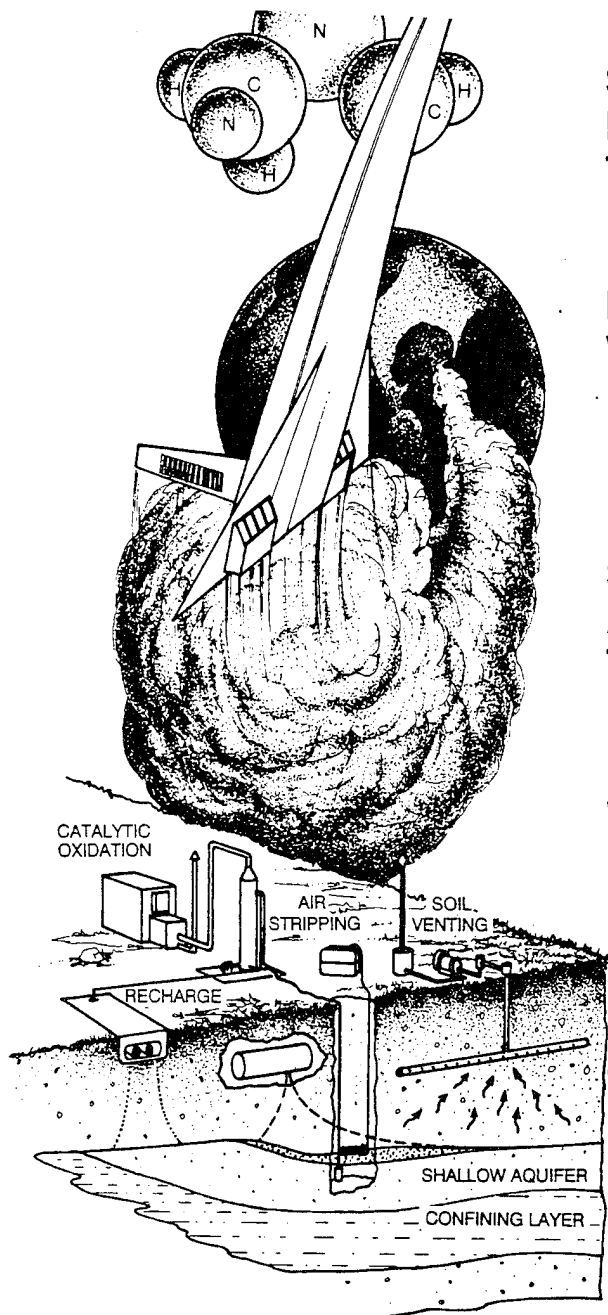


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SKID-MOUNTED SODIUM SULFIDE/ FERROUS SULFATE METAL PRECIPITA- TION PROJECT

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FINAL REPORT

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13. ABSTRACT (Maximum 200 words) The objective of this Phase I research project was to develop the data and design criteria necessary to design and test the skid-mounted sodium sulfide/ferrous sulfate process for small point-source wastewater generators throughout the Air Force. The work done included a paper survey of three Air Logistics Centers (ALCs), Columbus AFB, MS, and Wright-Patterson AFB, OH; laboratory testing of two Columbus AFB wastestreams; and design and construction of the mobile wastetreatment unit. Results from Columbus AFB show the process is capable of removing heavy metals from the tested wastestream to discharge standards. However, there were organic constituents in the Columbus AFB wastestream that this process would not remove and therefore would prevent discharge. The mobile unit was not tested; testing is planned for Phase II.				
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PREFACE

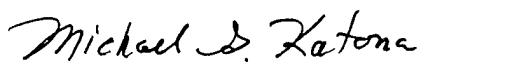
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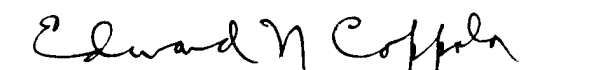
This Phase I final report describes the development of a mobile wastewater treatment process for Air Force point source generators. The work was performed between June 1991 and October 1992. The Air Force project officer was Lieutenant Phillip P. Brown.

This report has been reviewed by the Public Affairs Officer (PA) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nationals.

This report has been reviewed and is approved for public release.


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EXECUTIVE SUMMARY

A. OBJECTIVE:

The objectives of this project were to design a skid-mounted unit for testing the Sodium Sulfide/Ferrous Sulfate (SS/FS) process at a reduced scale (1 to 10 gpm) that would allow for definition of operating parameters for the design of a field unit for use by the Air Force, to identify potential wastestreams for testing of the unit and laboratory testing on these streams to determine process parameters to be factored into the field unit design.

B. BACKGROUND

The SS/FS process has been successfully employed in a number of large water treatment plants. This success lead to a plan to scale the process down for application to small point-source dischargers. Many facilities have low flow (gallons/month) wastewater streams containing heavy metals, particularly chromium, but because of inadequate water treatment facilities must pay to have these waters disposed of at certified disposal facilities. It is anticipated that the successful completion of this project will produce a small, easily applied version of the SS/FS process that will alleviate the high cost of disposal of these heavy metal wastes by concentrating them and reducing their volume.

C. SCOPE

The scope of this project was to generate enough information to apply the SS/FS process to the treatment of a number of point-source industrial wastewaters. Phase I consisted of the following; performing a survey of the Air Logistic Command bases to classify possible locations to which the SS/FS process could be applied, constructing a skid-mounted R&D unit, and evaluating the treatment process and the treatment technology.

D. METHODOLOGY

Surveys were taken of several bases to determine the quantity and type of waste generated. This was done to ascertain facilities for testing the R&D unit, and to establish design parameters for the R&D unit.

Laboratory jar tests were performed on wastewater from selected streams from Columbus Air Force Base (CAFB) to determine process parameters for design and testing of the skid-mounted unit.

As an outcome of the testing on CAFB water it became apparent that an organics loading in the wastewater of 3,000 ppm or greater might interfere with the SS/FS process. As a result work was done to identify an organics treatment technology that would be compatible with the process. After completion of a literature search it was determined that three technologies, the Fenton Process, the Brinecell® Process and activated carbon absorption were good candidates and limited testing was done on each of these technologies.

E. TEST DESCRIPTION

Laboratory testing was conducted in two stages, SS/FS process, organic treatment process parameter characterization for the CAFB Corrosion Control Facility effluent water, and investigation of potentially compatible organic treatment processes.

SS/FS process parameter characterization began upon receiving proper access to CAFB by responsible personnel. The SS/FS process was optimized in jar tests using four primary reagent concentrations. For each concentration of reagent the pH of the solution was adjusted and the sodium sulfide solution was added to the wastewater. The solution was mixed and the ferrous sulfate solution added, again the pH was adjusted to the optimum pH for hexavalent chromium reduction and metal precipitation. Polymer requirements were then determined for the optimum sodium sulfide, ferrous sulfate, and pH values.

Organic treatment process identification began after determining that the Fenton and Brinecell® were the most identifiably effective to use and the activated carbon was best used as a polishing step. Each technology was evaluated at laboratory scale. A brief description of each follows. During the Fenton process solutions are mixed and pH adjusted, hydrogen peroxide is added and the pH of the solution checked and maintained between three and five. Reaction time in these tests was approximately 16 to 24 hours.

Brinecell® process uses an electrode to generate hydrogen peroxide, ozone, and chlorine to oxidize the organic material in the wastewater.

Activated carbon adsorption polishing was evaluated as polishing stream by treating samples from the Fenton process and the sodium sulfide/ferrous sulfate process.

F. RESULTS

At CAFB there is a need to reduce the amount of chromium in the wastewater. The initial amount of hexavalent chromium was .04 mg/L. Total chromium concentration was 9.0 mg/L and was found capable of being reduced to 3.75 mg/L using filtration (Whatman #4 filter paper). The resultant turbidity was found to be 1.00 mg/L sulfide, the turbidities were reduced when the ferrous iron concentration was increased to 1.00 mg/L or greater, however by increasing ferrous concentration sludge volume is also increased. The turbidity was achieved at anionic polymer

concentrations ranging from 0.25 mg/L to 0.75 mg/L and cationic polymer concentrations of 20 mg/l.

Although there are several methods to treat organic compounds in wastewater it was deduced that chemical oxidation with subsequent carbon polishing was to be the most efficient. Carbon polishing is an acceptable method to be used if the TTO are not completely oxidized during chemical oxidation. There were two forms of chemical oxidation process which were found to work most effectively at Columbus Air Force Base and when could be coupled to the SS/FS metal treatment process, those were Fenton process and ozonation/oxidation using the Brinecell® electrolysis process.

G. CONCLUSIONS

Due to the concentrations of heavy metals as well as TTOs in the wastewater at CAFB, it would be necessary to treat the wastewater with the SS/FS process and an organic treatment process before discharge to the base water treatment plant. Although it is evident that the Brinecell® process has application to the treatment of industrial wastewater, it still needs to be looked at on a large scale.

H. RECOMMENDATIONS

By the previous application of the SS/FS process at Tinker Air Force Base and by the laboratory testing conducted at the CAFB, it is apparent that the process is capable of removing heavy metals to discharge requirements for industrial wastewaters containing heavy metals. However, operating and process parameters for a mobile processing unit to serve the needs of small point-source generators need to be established. This can be accomplished by identifying for testing the skid-mounted unit constructed under this project. With the process and operation duties gathered in these tests, a field unit could be design for application at any number of sites.

Recommendations for Phase II of the project include; expanding the survey of wastewaters to include laboratory testing, identify all of the contributing components which may cause the amount of TTOs and heavy metals to be excessive of the required discharge to a domestic sewage treatment facility, conduct laboratory tests to determine the most cost efficient and technically practical method for treatment and/or removal.

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LIST OF ACRONYMS

AFB -- Air Force Base
AFCESA -- Air Force Civil Engineering Support Agency
ALCs -- Air Logistic Centers
BOD -- biochemical oxygen demand
CAFB -- Columbus Air Force Base
CCF -- Corrosion Control Facility
COD -- chemical oxygen demand
EDTA -- ethylenediaminetetraacetic acid
EPA -- Environmental Protection Agency
ERAD -- Environmental Research and Development, Inc.
IWTP -- industrial wastewater treatment plant
MEK -- methyl ethyl ketone
MSDS -- material safety data sheets
NPDES -- National Pollutant Discharge Elimination System
O&M -- operation and maintenance
PCBs -- polychlorinated biphenyls
PCE -- tetrachloroethylene
R&D -- research and development
TCE -- trichloroethylene
TTO -- total toxic organics

SECTION I INTRODUCTION

A. OBJECTIVE

The sodium sulfide/ferrous sulfate process is an Air Force-patented technology that has been demonstrated to precipitate heavy metals from wastewater generated by degreasing, paint stripping, and electroplating metal treatment operations. The process reduces hazardous hexavalent chromium to the less soluble trivalent state and precipitates it and other heavy metals such as nickel, cadmium, zinc, copper, and lead from wastewater. An additional benefit of the process is an apparent reduction in the quantity of sludge generated, compared to typical lime precipitation treatment. Although the sodium sulfide/ferrous sulfate process was developed for electroplating process wastewater, it has potential application to the treatment of many low metal-bearing wastewaters to meet increasingly stringent National Pollutant Discharge Elimination System (NPDES) requirements.

The objective of this project is to develop a method for applying the technology to point-source waste streams, particularly at small Air Force facilities. These small facilities typically do not have industrial wastewater treatment systems and are incurring significant costs for disposal of heavy metal wastewaters at hazardous waste facilities. Development for this application involved:

- identifying the heavy metal-bearing waste streams;
- characterizing these waste streams; and
- laboratory testing to determine the applicability of the process, potential interferences to the process, and required chemical operating parameters.

B. BACKGROUND

1. Project History

For this project, the original objectives of the Air Force were specified in the Statement of Work authorizing the contractor to proceed. These objectives were

- (a.) develop the data required to optimize the operation of the process for a number of point-source generating applications; and
- (b.) develop a skid-mounted system for Columbus Air Force Base (CAFB).

The steps developed to accomplish these objectives were

- perform a survey of the waste streams at CAFB and at other Air Force facilities;
- perform lab-scale testing and analysis of waste streams;
- design and build two mobile research and development (R&D) sodium sulfide/ferrous sulfate process units;
- perform pilot-scale testing of the sodium sulfide/ferrous sulfate process at various bases using the mobile R&D units;
- use data derived from pilot-scale testing to perform process design scaleups and evaluate the process economics; and
- write a final report detailing all results and accomplishments.

The project began with a survey of CAFB waste streams. CAFB had an immediate need to treat the effluent from the Corrosion Control Facility (CCF) because the wastewater could no longer be discharged to the domestic sewage treatment plant on the base and was being disposed as a hazardous waste at \$7/gallon (1991 cost provided by CAFB personnel). Characterization of the wastewater showed it contained heavy metals and had a total toxic organics (TTO) concentration greater than local discharge requirements. Based on these results, two activities were undertaken. The first involved the laboratory analysis of the applicability of the sodium sulfide/ferrous sulfate process to the CAFB wastewater. The second was a study of technologies capable of removing the organic compounds.

As these two activities proceeded, it became apparent that organic and heavy metals removal would be required to meet the requirements of the original Statement of Work, i.e., develop a skid-mounted system for CAFB. Development of a treatment unit for organics to be used with the sodium sulfide/ferrous sulfate process was outside the original scope of the project; therefore, it was not pursued beyond the organic treatment technology study.

Work on the specific details for CAFB affected the overall progress of the project. These delays made completing the goals of the original Statement of Work impossible under the existing funding and schedule constraints. Consequently, a revised Statement of Work was issued dividing the work into two phases. Phase I, which was to be accomplished with remaining funds, involved completing one mobile R&D unit (including all necessary operating and maintenance documentation), surveying the Air Logistics Center (ALC) bases for heavy metal-bearing waste streams, and writing an interim Phase I report. Phase II objectives, dependent on future funding, are to produce a technical data package for a conceptual design of a full-scale sodium sulfide/ferrous sulfate treatment unit and an applications manual to be used as a guide for applying the technology to candidate waste streams.

2. The Sodium Sulfide/Ferrous Sulfate Metal Treatment Process

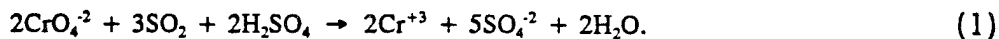
The electroplating process includes degreasing, alkaline cleaning, electrocleaning, acidizing, and electrochemical deposition of the protective metal. The process metals and chemical solutions are carried into wastewaters that must be treated at wastewater treatment plants (Reference 1). Other wastewaters result from engine-cleaning and paint-stripping processes. These wastewaters contain hexavalent chromium, cadmium, trivalent chromium, copper, lead, nickel, and zinc as well as complexing and chelating agents such as ammonia, cyanides, ethylenediaminetetraacetic acid (EDTA), phosphates, tartrates, and other contaminants such as phenols, oils, and greases. To comply with the NPDES requirements before discharge, the wastewater must be treated to remove these contaminants.

In 1980, metal-bearing sludges generated at all industrial wastewater treatment facilities were classified as hazardous per regulations issued by the Environmental Protection Agency (EPA). These sludges require special handling and disposal in hazardous waste landfills (Reference 1), which can be costly.

a. Hexavalent Chromium Treatment

The common treatment for metal finishing wastewater consists of separating oil and grease, destroying cyanides, neutralizing, separating the metal hydroxides, and finally, disposing of the sludge (Reference 2).

Hexavalent chromium cannot be precipitated without prior reduction to trivalent chromium, and reduction with sulfur dioxide is the most common method used on a large scale (Reference 3). The reduction reaction using sulfur dioxide is:

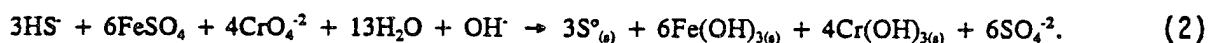


Other methods of reduction include using sodium sulfite, sodium bisulfite, and ferrous compounds. The quantity of sludge produced by the different reducing agents can vary dramatically.

Sulfur compounds (S^{+4}) reduce hexavalent chromium at pH of less than 3; the rate slows logarithmically with increased pH. Sulfides (S^{-2}) also reduce hexavalent chromium at acidic pHs. Sulfides convert to hydrogen sulfide gas at acidic conditions and are released as a toxic gas if not confined to the aqueous medium. Under closed conditions and using peroxide for oxidation of the residual sulfide before discharge, an acidic sulfide process is effective for reducing hexavalent chromium (Reference 1). At neutral or alkaline pH ranges, the above reaction rate is unacceptably slow.

If sulfide is used as a reducing agent at neutral pH, ferrous ion is required as a catalyst. By itself, ferrous ion is not efficient in reducing hexavalent chromium since only one electron is available per iron atom, and a large quantity of iron hydroxide sludge is produced. However, the ferrous ion can reduce hexavalent chromium at alkaline pH and is an effective coagulant.

When the ferrous ion, as ferrous sulfate, is present with sulfide, the hexavalent chromium is rapidly reduced at neutral and alkaline pH. The theoretical basis for ferrous and sulfide reduction of hexavalent chromium is based on the 1983 report by Higgins and Sater (Reference 4). The ferrous ion appears to catalyze the sulfide reaction. Near a pH of 8.5 to 10, the effectiveness of the sulfide ion is reduced; over this pH range, the ferrous ion (Fe^{+2}) is converted to the ferric ion (Fe^{+3}). At neutral pH, the proposed reaction for equivalent doses of ferrous ion and sulfide (S^{-2}) is (Reference 4):



This reaction would be favored slightly by an increase in Ph. Increasing the ratio of the sulfide to ferrous ion reduces the effect of increased pH. Ferrous ion and sulfide appear to be the best combination for reducing and removing hexavalent chromium at neutral or near neutral conditions.

b. Heavy Metal Treatment

The standard applied treatment technology for removing heavy metals is chemical precipitation. If lime is used, precipitation is essentially complete for copper, zinc, iron, manganese, nickel, and cobalt; cadmium, mercury, and lead may require additional pH adjustment with soda ash or sodium sulfide for precipitation (Reference 5). Chlorination may be needed to destroy complex organic metallic compounds (such as cyanide) before precipitation. Other methods of removal include electrodeposition, reverse osmosis, solvent extraction, ultrafiltration, ion exchange, and activated carbon adsorption. In hydroxide precipitation, sludge from the clarifier will contain up to three percent solids, depending on the settling time. Further dewatering will produce a sludge containing 12-18 percent solids (Reference 6).

Most metal hydroxides have a relatively high solubility; the solubility of the metal hydroxide complex increases at high pH. Many of the metal hydroxide precipitates are amphoteric in nature and dissolve at high pH values according to the following reaction:



where M is the metal ion (Reference 7).

Hydroxide precipitation of all heavy metals present cannot be relied on because the minimum solubilities of the various metals do not occur at the same pH. In addition, the presence of complexing agents, such as ammonia and EDTA, prevents effective precipitation (References 8 and 9).

The high reactivity of sulfides (HS^- , S^{2-}) with heavy metal ions and the low solubility of heavy metal sulfides over a broad pH range are attractive features when compared to the corresponding hydroxide precipitation processes (Reference 8). The hydroxide process generally removes metals down to one or two mg/L (Reference 6). The metal sulfides tend to be at least four or five orders of magnitude less soluble than their corresponding metal hydroxides (Reference 8).

Metal precipitation by soluble sulfides requires a sulfide source more soluble than the metal to be precipitated, such as sodium sulfide (Reference 9). Sodium sulfide disassociates readily into sodium and sulfide ions as follows:



Under acidic conditions, the free sulfide can react with the water to form free hydrogen sulfide gas or can react to precipitate a heavy metal.



Advantages of the sulfide process are the low solubilities of most metal sulfides, the ability of the sulfide to reduce hexavalent chromium at neutral or basic pH in the presence of the ferrous ion, and the increased ability to precipitate metals that are complexed with at least some of the weaker complexing agents. The odor and toxicity of hydrogen sulfide are not a problem under normal alkaline operating conditions (Reference 6).

Air Force Civil Engineering Support Agency (AFCESA) Report ESL-TR-87-39 contains an extensive literature review describing the kinetics and chemistry of the reduction process for hexavalent chromium species and the metal precipitation processes (Reference 10). Under funding from the AFCESA at Tyndall AFB, the sodium sulfide/ferrous sulfate method of reducing hexavalent chromium and removing the heavy metals from electroplating and industrial wastewater was technically verified by laboratory tests, pilot field tests, and full-scale implementation of the process in the existing industrial wastewater treatment plant (IWTP) at Tinker AFB, Oklahoma. The process has been in operation at the Tinker AFB IWTP since July 1988, and the metals in the effluent of the IWTP have remained well below NPDES permit requirements (References 11, 12, and 13). Cost comparison of the sodium sulfide/ferrous sulfate process and the sulfuric acid/sulfur dioxide/lime process showed a chemical treatment, sludge removal, and disposal cost reduction on a yearly basis.

The sodium sulfide/ferrous sulfate process was patented by the United States Air Force (Reference 14), and the Air Force granted Environmental Research and Development, Inc. (ERAD), an exclusive license to the process.

C. SCOPE

The scope of this project was to develop the data necessary to apply the sodium sulfide/ferrous sulfate process to the treatment of a number of point-source industrial wastewaters. Completion of Phase I included the following:

- (a.) Performing a survey of the ALCs to identify potential point-source waste streams to which the sodium sulfide/ferrous sulfate process could be applied. The ALCs were chosen for this survey because of the variety and volume of production processes at these facilities.
- (b.) Design and construction of one skid-mounted R&D sodium sulfide/ferrous sulfate unit for evaluation of the process at point-source waste streams. This included preparing an O&M manual for the unit.

(c.) Laboratory evaluation of the sodium sulfide/ferrous sulfate metal precipitation process to determine the requirements for treatment of the wastewater produced at CAFB CCF. Because of the need at CAFB to discharge to a domestic sewage treatment plant and the concentration of TTO in this wastewater, this included a laboratory evaluation of the treatment technology to remove the organic compounds (and thus the listed TTO).

Phase II of this project will include the following:

- performing a detailed survey of the waste streams identified at the ALCs as potential candidates for application of the sodium sulfide/ferrous sulfate process;
- laboratory-scale testing of candidate waste streams;
- pilot-scale testing of selected waste streams using the R&D mobile unit;
- generating a technical data package, which will consist of a conceptual design for a full-scale sodium sulfide/ferrous sulfate unit;
- developing an applications manual to evaluate the use of the sodium sulfide/ferrous sulfate process at any Air Force base; and
- producing a final report.

SECTION II PROCEDURES

A. TEST PROCEDURES

1. Sodium Sulfide/Ferrous Sulfate Process

Access to CCF wastewater was obtained through the cooperation of responsible personnel. The sodium sulfide/ferrous sulfate process was evaluated in jar tests using the Phipps and Bird 6-paddle jar test apparatus. One-liter beakers were used, and each beaker was filled with 1,000 mL of the CAFB wastewater sample.

a. Reagent Concentration

Preparation of the four primary reagents of the process are given below.

Solutions of ferrous ion and sulfide were made to 1,000 mg/L using ferrous sulfate heptahydrate ($\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$) and sodium sulfide monohydrate ($\text{Na}_2\text{S} \cdot 9\text{H}_2\text{O}$). Sulfuric acid [0.2 mL of 5.25 normal (N)] was added to the water before adding the ferrous sulfate heptahydrate to prevent the formation of ferric iron. Betz® 1195 cationic polymer was made to 1,000 mg/L using one mL of the neat liquid polymer and diluting to 1,000 mL. Betz® 1120 anionic polymer was made to 100 mg/L using a 0.5-percent sample. Potable water was used for all solutions.

b. Sulfide and Ferrous Iron Optimization

Initial tests were conducted to optimize the sulfide and ferrous iron concentrations required to reduce the hexavalent chromium to trivalent and achieve metal precipitation. The pH of the solution was adjusted to 7.2 with a 5 normal (N) sodium hydroxide solution, and the sulfide solution was added to the wastewater. The solution was mixed for minutes at 120 rpm, then the ferrous solution was added. The pH after ferrous iron addition was adjusted to 7.2-7.5, which is the optimum pH for hexavalent chromium reduction and metal precipitation found during previous testing. The pH was determined using a Corning 107 pH/temperature meter calibrated with pH 7 and pH 10 buffers. The reacted solution was analyzed for hexavalent chromium using the HACH 1,5-diphenylcarbohydrazide method for hexavalent chromium for water and wastewater and a HACH DR2000 spectrophotometer. The sulfide concentration was varied at fixed ferrous iron concentrations. The results of this optimization appear in Section III.

c. Polymer Requirements

Polymer requirements were determined at the optimum sulfide, ferrous, and pH requirements. The effects of varying concentrations of cationic and anionic polymers was tested and determined through observation of the type of floc formed and settling characteristics and by analyzing the resulting solution turbidity. Turbidity was analyzed using the HACH absorptometric method and the HACH DR2000 spectrophotometer.

d. Routine Testing

Once the optimization of the sulfide and ferrous iron concentration was determined and a range of polymer concentrations was established, routine testing of the CCF wastewater used the following procedure.

After the addition of the sulfide and ferrous iron and adjusting to the optimum pH, the desired polymer was added. The solution was then mixed for two minutes at 120 rpm, and if the second polymer was required by the test parameters, it was then added and mixed for two minutes at 120 rpm. In either procedure, the resulting solution was then mixed for two minutes at 20 rpm. The paddles were removed, and the solution was allowed to settle for five minutes. Turbidity was determined after filtering the solution through a cotton plug placed loosely in the bottom cone of a funnel; the cotton plug is representative of filtering the clarifier effluent through a sludge bed.

2. Organic Treatment Processes

The Fenton and Brinecell® processes for TTO removal were determined to be the most compatible with the sodium sulfide/ferrous sulfate process. It was determined the organic treatment should precede the metals treatment. The procedures for metals removal after TTO treatment were the same as those described in Section 1 above.

a. Fenton Process

The Fenton process was evaluated using the Phipps and Bird jar test apparatus. Initial testing was conducted with 200 mL samples in 600 mL beakers, which allowed room in the beaker for any foaming that might occur during the reaction and prevent any loss of sample. The solutions were mixed at 100 rpm, and the pH of the solution was adjusted to four with a 5.25 N sulfuric acid solution. The ferrous iron was prepared as described above except that a 10,000 mg/L iron solution was prepared to minimize the volume of ferrous solution required and the ferrous iron was then added to the solution at the desired concentration. A commercially available 50-volume-percent hydrogen peroxide from Fischer Scientific or HACH Chemical was used for all hydrogen peroxide addition; the concentration of this solution was 565,000 mg/L hydrogen peroxide. The hydrogen peroxide was added to the solution at the desired concentration. The pH of the

solution was checked and maintained between three and five with either caustic or sulfuric acid solutions and was allowed to react. Generally, the reaction time was between 16 to 24 hours. Hydrogen peroxide test paper was used to check if the hydrogen peroxide was totally reacted, and when no hydrogen peroxide was detected, the mixing was stopped, the sample was filtered through cotton and a sample was collected for COD analysis.

A 1-Liter beaker was filled to the 1-Liter mark with the wastewater, and stirring started at 100 rpm on the jar test apparatus. The pH of the solution was adjusted to pH 4 with sulfuric acid. Ferrous iron at 0.2 mg/L ferrous iron was added per one mg/L COD. If the COD was 1,000 mg/L, then 200 mg/L ferrous iron was required (or 20 mL of a 10,000 mg/L ferrous iron solution). (The 10,000 mg/L ferrous iron solution was made up by adding 0.2 mL of concentrated sulfuric acid and 25 g of ferrous sulfate heptahydrate to 500 mL of water.) Hydrogen peroxide was added to the solution at two mg/L hydrogen peroxide per one mg/L COD. If the COD was 1,000 mg/L, then 2,000 mg/L hydrogen peroxide was required. The hydrogen peroxide solution was 565,000 mg/L hydrogen peroxide; therefore, for 2,000 mg/L hydrogen peroxide, 3.54 mL of the hydrogen peroxide solution was required. The pH of the solution was maintained between three and five with either caustic (potassium hydroxide or sodium hydroxide) or sulfuric acid (5.25 N). The solution was allowed to mix for 24 hours. After 24 hours, the solution was checked with a hydrogen peroxide strip to ensure the hydrogen peroxide had been used up during the reaction. The treated wastewater was then analyzed for COD. The pH of the solution was adjusted to 7.2 to 7.5 with caustic. Sulfide at 3.5 mg/L sulfide was added to the solution; this would be 0.35 mL of a 10,000 mg/L sulfide solution. (10,000 mg/L sulfide is 37.5 grams of the sodium sulfide monohydrate in 500 mL of water.) The pH of the solution was adjusted to 7.2 to 7.5 with sulfuric acid, and the solution was allowed to mix for two to five minutes. Betz®1195 cationic polymer at 10 mg/L was then added to the solution. (A 5,000 mg/L solution of Betz®1195 was made by adding 0.5 mL of the neat polymer to 100 mL of water and shaking well.) Two milliliters of the 5,000 mg/L solution was added to achieve 10 mg/L of the Betz®1195, and the solution was allowed to mix for two to five minutes. Betz®1120 anionic polymer was added at 0.5 mg/L. (A 100 mg/L solution of the Betz®1120 was made by adding two mL of the 5,000 mg/L Betz®1120 sample to 100 mL of water and shaking well.) Five milliliters of this solution was added to the treated wastewater to achieve 0.5 mg/L of the Betz®1120, and the solution was allowed to mix for two to five minutes. The stirring was slowed to 10 rpm, and the solution was allowed to stir at this speed for five minutes. The stirring was then stopped, and the precipitate was allowed to settle. The clear solution was then filtered through cotton, and a sample was collected for metal analysis. Sufficient sample was prepared in this manner for TTO analysis.

After this optimization procedure produced a range of reagent concentration for the CCF wastewater, a sample was prepared by the following procedure for TTO analysis by a contract laboratory.

b. Brinecell® Process

The Brinecell® process uses an electrode to create hydrogen peroxide, ozone, and chlorine to oxidize the organics present in the wastewater; this oxidation is dependent on the salt (Sodium Chloride, NaCl) concentration and the organic compounds being oxidized. A laboratory unit was leased to evaluate the process. Details of this evaluation are shown in Section III, and the data from this evaluation are shown in Appendix D.

c. Carbon Polishing

To evaluate carbon polishing, samples were treated by the Fenton process and the sodium sulfide/ferrous sulfate process. The treated samples were filtered and preweighed, and samples of the carbon were added to 200 mL of the sample. Each sample was stirred, filtered, and analyzed for COD.

B. ANALYTICAL PROCEDURES

Hexavalent chromium was analyzed by using the HACH 1,5-diphenylcarbohydrazide method. For total metal and phosphorus analysis, the samples were digested using a HACH Digesdahl Apparatus by the methods provided with the apparatus. With deionized water, 40 mL samples were digested and brought to 100 mL. To provide sufficient samples for analysis, two batches of each sample were digested, and the digested samples were analyzed for phosphorus using the HACH PhosVer 3 (ascorbic acid) method. The digested samples were analyzed for the heavy metals using a Varian Spectra 12 atomic adsorption spectrophotometer. Turbidity was analyzed using the HACH absorptometric method. All colorimetric analysis were read using the HACH DR2000 spectrophotometer. The COD was determined using the HACH COD reactor and HACH prepackaged COD digestion vials.

SECTION III RESULTS

A. AIR FORCE SURVEYS

A survey of the ALCs was conducted to better define the production processes generating heavy metals and the type and volume of waste generated. The results of the survey will be used in Phase II as an aid in identifying the facilities for testing the R&D unit. In Phase II, the wastestream will be identified and characterized, and tests will be conducted to evaluate the requirements for the sodium sulfide/ferrous sulfate process.

A survey form to identify the volume and type of waste generated was prepared and sent with a cover letter describing the program objectives and the sodium sulfide/ferrous sulfate process to the five ALCs and to Wright-Patterson Air Force Base. However, before sending the survey form, contacts were established at these facilities, and the personnel were contacted by telephone to explain the purpose of the survey and establish the addresses of the individuals to receive the survey forms. The contacts are listed in Table 1. Follow-up calls were made to ensure receipt and to answer questions. The completed survey forms for the facilities responding are provided in Appendix A.

Completed surveys were received from Kelly AFB and Wright-Patterson AFB. The information for Tinker AFB was obtained by visiting the individuals listed on the survey forms.

Hill AFB was not receptive to the survey, and McClellan AFB is still in the process of gathering the information. Personnel changes had occurred at Warner Robins AFB, and the new personnel indicated they would complete the survey forms; however, to date these forms have not been received.

TABLE 1. LIST OF AIR FORCE PERSONNEL WHO WERE SENT THE PROCESS SURVEY.	
Hill AFB Mr. Bob Van Orman Environmental Management Building 800 - 9B Hill AFB, UT 84056-5000	Kelly AFB Mr. Terry Schaumberg Environmental Management Program Kelly AFB, TX 78241-5000
McClellan AFB Mr. Steve Mayer SM-ALC, TIM-1 McClellan AFB, CA 95652	Tinker AFB Mr. Bill Cain Mr. Mike Patry OC-ALC/LAPEP OC-ALC/MAENP Tinker AFB, OK 73145 Mr. Carlos Nazarios OC-ALC/LIPEB Tinker AFB, OK 73145
Warner Robins AFB Ms. Margaret Harris Mr. Shaun Politino WR-ALC/EMM WR-ALC/EMC Robins AFB, GA 31098	Wright Patterson AFB Colonel Tom Walker 2750 ABW/EM Wright Patterson AFB, OH 45433

1. McClellan Air Force Base

In addition to the survey, McClellan AFB was visited in October 1991 to determine potential needs for the sodium sulfide/ferrous sulfate process. Many of the waste streams reviewed were small and are operated as the need arises, such as paint booths or small parts degreasing and allodyning areas. Although these would represent some of the concentration ranges for the processes, it was felt the streams are too small for process evaluation with the R&D unit.

2. Wright-Patterson Air Force Base

Wright-Patterson AFB named two facilities, the Printed Circuit Board Shop and the Plating Shop, generating heavy metal-containing wastewaters. The Plating Shop generates 15,000 gal/day of wastewater; the volume of wastewater generated at the Printed Circuit Board Shop was unknown. Wright-Patterson AFB discharges all of its wastewater to the City of Dayton at a cost of \$92,102.30/mo (\$0.98 per 1,000 gallons). The sludge disposal costs are \$1.75-\$3.25 per pound depending on which contract line item is used. The personnel contacted expressed interest in the types and options of pretreatment systems available. Appendix A provides the analysis of the wastewaters for both the Printed Circuit Board Shop and the Plating Shop.

3. Kelly Air Force Base

Kelly AFB completed survey forms for four facilities. These were the Plating Facility where jet engine parts are repaired, the Bicarbonate of Soda Stripping Facility, the Aircraft Paint Stripper Waste Facility, and the Machine Shops where cooling/cutting fluids are generated. Repairs include chrome, nickel, silver, and cadmium plating, anodizing, magnesium treatment, and ion vapor deposition. Depending on the concentration of the wastewater, the wastewaters are piped to the Central Wastewater Treatment Facility on the central wastewater line. At the treatment facility, the paint stripping and electroplating wastewaters are pretreated for heavy metal removal. The paint stripping wastewater is also treated for phenol removal. These pretreated wastewaters are then treated in the central wastewater line for further heavy metal removal and organic removal with an activated sludge system. The present heavy metal treatment process is a modified Sulfex process. Concentrated plating and stripping baths are trucked to the treatment facility for batch treatment, and the cooling and cutting fluids are disposed of as a hazardous waste (approximately 3,000 lbs/yr).

4. Tinker Air Force Base

Meetings were held with Mr. Mike Patry of the Chemical Cleaning and Plating Facility and Mr. Bill Cain of the Aircraft Stripping and Painting Facility.

The Chemical Cleaning and Plating Facility presently recovers most of the heavy metals. Chromate recovery is presently in place to concentrate the chromate and return it to the process, nickel is recovered by ion exchange, cadmium has been replaced by a nickel-zinc coating. Water is recycled in the processing to minimize the wastewater generation and the requirement for additional water; approximately 60,000 gallons of wastewater is generated per day at the facility. The wastewater containing approximately 10 to 20 mg/L of chromium and nickel is pretreated using sodium bisulfite and sulfuric acid for chromium reduction and caustic for heavy metal precipitation process. Because of the difference in the minimum solubilities of the hydroxides of the chromium and nickel, the pH is balanced to minimize the discharge of these metals. The treated effluent flows to

the Tinker AFB IWTP. Mike Patry is interested in implementing the sodium sulfide/ferrous sulfate process in the pretreatment facility. Applicability of the metal treatment to this industrial wastewater was demonstrated in the development of the sodium sulfide/ferrous sulfate process (Reference 10).

The aircraft stripping and painting operation can handle 200 aircraft per year; the general load is 75 percent KC135s and B52s. Every 8 years, an aircraft is completely refinished, and touch up is completed every four years. The primer coat of the aircraft has chromium or a leachable form of chrome, and this primer and the paint are removed with one of two types of methylene chloride phenol stripper. The approximately thirty 55-gallon drums/month of paint sludge from the stripping is drummed and disposed of as a hazardous waste. A limited amount of the stripper goes to the IWTP D1 and D2 tanks where it is metered into the treatment plant. Approximately 60 aircraft a year get a full allodyne treatment with 500-600 gallons of allodyne solution having 2 to 3 percent of chromium applied per aircraft. The wastewater and rinse water from the allodyning process go to the treatment plant. Approximately 40 aircraft receive touch up per year. Allodyne is applied with cheese cloth, and the contaminated cheese cloth is drummed; approximately two drum/month or 30 drum/year of the contaminated rags are generated.

Some small parts are cleaned by bead blasting; however, the soft skins of the aircrafts do not permit bead blasting on these. Tinker AFB is looking at a high-pressure water process in which the water could be filtered and recycled and the metals could be monitored. Tinker AFB has investigated nonchromated allodyning; however, the nonchromated solutions did not give the adhesion or corrosion protection required in coupon tests. Presently, use of a benzyl alcohol stripper is being investigated. This stripper is effective on the primer but requires additional time on the topcoat. However, the time requirement would not seriously impact production; consequently, if the use of this stripper is accepted, it would eliminate or reduce the requirement for the methylene chloride phenol stripper.

B. COLUMBUS AIR FORCE BASE

1. Wastestream Description

Columbus AFB was identified early in the project as a potential location for testing the process. Contacts with key personnel were made to identify waste streams and to initiate laboratory testing. Columbus AFB was visited on May 9 and 10, 1991, to review: 1) the facilities generating metal-bearing wastewater, 2) the wastewater characteristics, 3) the volume of the wastewater generated, and 4) the proposed location for a mobile metal pretreatment plant.

a. Corrosion Control Facility

The primary facility to locate a mobile unit was the CCF in Building 262. At this facility, aircraft that were previously stripped (via bead blasting) at Randolph AFB were processed and painted. The process included a

washdown, allodyning, rinsing, a methyl ethyl ketone (MEK) wipedown, primer application, and paint application. On an average, one full aircraft was treated and three aircraft were touched up per week; this produced approximately 1,000 gallons of wastewater. The building washdown had been discontinued due to the high cost of waste disposal; however, the personnel at this facility would like to be able to continue the washdown. This would bring the wastewater generation to 3,000 gal/week but would eliminate the collection of dust, which creates a nuisance when painting.

A 10,000-gallon underground storage tank is located outside Building 262. This tank is divided into two compartments with approximately 2,000 gallons used for settling out the solids before the wastewater flows to the remaining tank. The tank was originally piped to flow to the domestic sewage treatment facility of the base, but this flow was stopped in April 1990. Presently, the wastewater is pumped for hazardous waste disposal about every 90 days, and the disposal cost is about \$7/gal (1991 cost as reported by CAFB personnel).

The Material Safety Data Sheets (MSDS) for the chemicals used in the process were reviewed. The wastewater was comprised of rinse water from the allodyning solution containing chromium trioxide and nitric acid; a corrosion prevention compound that is a mild aromatic (the aromatic compound was not defined) and 77 percent volatile; and small amounts of paint stripper, primer, and polyurethane paint. According to the MSDS, the paint stripper manufactured by B&B Paint Chemical Company is a viscous liquid with solvent odors. Generally, the paint stripper was only used for touchup and was vacuumed up after stripping and drummed for disposal. The cleaning compound was a viscous off-white acidic liquid; however, the components could not be identified from the MSDS.

A 1-gallon sample of wastewater was collected from a drum for laboratory testing; this wastewater was supposedly representative of the wastewater contained in the holding tank. A sample of the composite wastewater could not be collected since it had been pumped out the previous day. The wastewater was analyzed for heavy metals and COD. The analyses are listed in Table 2. Column 2 of Table 2 shows the results from an analysis on a prior batch of wastewater; these data were provided by CAFB personnel.

TABLE 2. WASTEWATER ANALYSIS-CCF.		
CONSTITUENT	SAMPLE (MAY 9, 1991) (MG/L)	PRIOR ANALYSIS ^a (MG/L)
Cr ⁺⁶	7	---
Cr	15	26
Cd	0.18	0.34
Cu	0.25	0.09
Fe	0.98	0.27
Pb	0.23	---
Ni	0.01	---
P	35	---
TOC	---	<200 µg/L
COD	2,300	---
^a The date of the analysis was not available.		

If the treated wastewater had been discharged to the CAFB domestic sewage treatment plant, it would have been required to comply with all requirements of 40 CFR 122.41(a). The discharge limits are shown in Table 3 (Reference 15 and 16). The 5-day biochemical oxygen demand (BOD) daily maximum is 45 mg/L and the monthly average is 30 mg/L. The only treatment process at the domestic sewage treatment plant is biological.

TABLE 3. BEST PRACTICAL CONTROL TECHNOLOGY EFFLUENT LIMITATIONS (Ref. 15 and 16)

POLLUTANT OR POLLUTANT PROPERTY	MAXIMUM FOR ANY ONE DAY (MG/L)	MONTHLY AVERAGE SHALL NOT EXCEED (MG/L)
Cadmium (T)	0.69	0.26
Chromium (T)	2.77	1.77
Copper (T)	3.38	2.07
Lead (T)	0.69	0.43
Nickel (T)	3.98	2.38
Silver (T)	0.43	0.24
Zinc (T)	2.61	1.48
Cyanide (T)	1.20	0.65
TTO	2.13	----
Oil & Grease	52	26
TSS	60	31
pH	6.0-9.0	6.0-9.0

An initial COD concentration of 2,300 mg/L was determined on the sample from Building 262. A sample was collected October 10, 1991, from the CCF and sent to Analytical Technologies, Inc., in Pensacola, Florida, for analysis of TTO. The results of this analysis are shown in Table 4. The wastewater from the CCF showed a TTO concentration of 13,019 parts per billion (ppb) (13.019 mg/L), which is greater than discharge requirements. The COD concentration in this wastewater sample for the CCF was 600 mg/L.

b. Parts Cleaning (Building 218)

The second area where a mobile unit may be required is in Building 218 where parts are cleaned. The wastewater is being filtered and recycled between two 450-gallon tanks in this building, and approximately half of each tank is evaporated weekly in normal operation. The two tanks are combined for the final rinse, then the initial tank is filled with new process water. As of May 1991, this process had been in place for approximately six months. Personnel interviewed expressed a desire to go back to the original operation where the two tanks are filled with fresh solution weekly; in this case, the process would generate about 900 gallons of wastewater weekly. No storage tanks are available for this

**TABLE 4. TOTAL TOXIC ORGANICS ANALYSIS FOR THE
CORROSION CONTROL FACILITY (OCTOBER 10,
1991).**

CCF—Building 262	
Acid Extractable	
Phenol	600 ppb
2,4-Dimethylphenol	42 ppb
Base Neutrals	
Isophorone	77 ppb
Purgibles	
Methylene Chloride	11,000 ppb
Tetrachloroethane	200 ppb
Toluene	1,100 ppb
Total	13,019 ppb

wastewater in Building 218. A sample of the final tank was collected in May 1991 for preliminary metal analysis. In September 1991, samples were collected from the hot rinse tank and cold rinse tank of Building 218 for heavy metal analysis. The results of the heavy metal analysis for May and September are shown in Table 5.

Samples were collected October 10, 1991, from the parts cleaning area and sent to Analytical Technologies, Inc., in Pensacola, Florida, for analysis of TTO. The results of these analyses are shown in Table 6; the TTO for parts cleaning were less than the discharge requirements of 2.13 mg/L TTO. The COD concentration of the wastewater sample was 175 and 33 mg/L, respectively for the hot water rinse tank and the cold water rinse tank for samples collected in September 1991. CAFB was in the process of designing a new parts cleaning facility, which would reduce or eliminate any wastewater from this process. The new process will not be on-line for at least 12-18 months.

TABLE 5. HEAVY METAL ANALYSIS—BUILDING 218 (PARTS CLEANING).	
Metal	Concentration (mg/L)
Hot Water Rinse (May 9, 1991)	1.22
Cadmium (T)	0.08
Copper (T)	0.21
Iron (T)	0.32
Lead (T)	0.31
Nickel (T)	3.01
Zinc (T)	0.22
Hot Water Rinse (September 17, 1991)	1.58
Cadmium (T)	0.07
Chromium (T)	0.15
Copper (T)	1.12
Iron (T)	1.77
Lead (T)	0.60
Nickel (T)	0.22
Zinc (T)	
Cold Water Rinse (September 17, 1991)	1.21
Cadmium (T)	0.05
Chromium (T)	0.12
Copper (T)	0.23
Iron (T)	1.73
Lead (T)	0.45
Nickel (T)	0.22
Zinc (T)	

c. Miscellaneous Waste Streams

Other wastewaters that may require treatment were from silver recovery from NDI, Building 246, and the Photo Lab in Building 820. Mr. Mark Meakins of DynCorp is the leadman at Building 246, and Mr. Bob Boland is the contact at the Photo Lab. Approximately 90 gallons of total waste is generated monthly from these two facilities. The samples were being analyzed for their silver concentration; however, to date these data have not been obtained.

TABLE 6. TOTAL TOXIC ORGANICS ANALYSIS FOR SAMPLES COLLECTED FROM BUILDING 218 (PARTS CLEANING) OCTOBER 10, 1991.	
Hot Water Rinse—Building 218	
Acid Extractable	BDL ^a
Base Neutrals	
Naphthalene	26 ppb
Purgibles	
1,1-Dichloroethane	9 ppb
1,1,1-Trichloroethane	600 ppb
Total	635 ppb
Cold Water Rinse—Building 218	
Acid Extractable	BDL ^a
Base Neutrals	BDL ^a
Purgibles	
1,1,1-Trichloroethane	26 ppb
Total	26 ppb
^a Below Detectable Limits	

A small amount of barium-containing wastewater from the medical facility may require treatment. The volume was not known, and several days would be required to collect sufficient sample for analysis.

2. Sodium Sulfide/Ferrous Sulfate Metal Treatment

Preliminary jar testing was conducted on the sample of wastewater collected in May 1991 from the CAFB CCF; the hexavalent chromium concentration of the wastewater was seven mg/L while the total chromium concentration was 15 mg/L. The tests indicated some interference with settling of the precipitate. The test conditions and results are shown in Appendix B. Chromium reduction was achieved with sulfide and ferrous concentrations at two mg/L sulfide:1.5 mg/L ferrous iron:1 mg/L hexavalent chromium.

A sample of wastewater was collected from the CCF storage tank on December 17, 1991. The wastewater was analyzed to evaluate the chemical requirements of the sodium sulfide/ferrous sulfate process for treating the wastewater to the concentrations required to achieve heavy metal discharge concentrations. The primary heavy metal requiring removal was chromium. The initial hexavalent chromium concentration was near the detection limit at 0.04 mg/L. The initial total chromium concentration was 9.0 mg/L; this concentration could be reduced to 3.75 mg/L by filtering the sample through Whatman #4 filter paper. Initial testing was conducted by treating the wastewater with varying concentrations of ferrous iron at fixed sulfide feed concentrations and monitoring the turbidity of the final solution after filtering through cotton. During these tests, the Betz®1195 and Betz®1120 concentrations were held constant at 10 and 0.5 mg/L, respectively. The resulting turbidities are shown in Figure 1. At 1.00 mg/L sulfide, the lower final turbidities were achieved when the ferrous iron concentration was increased to 1.0 mg/L or greater. The final turbidity at 0.5 mg/L sulfide was higher than that for 1.0 mg/L sulfide except at increased ferrous concentrations. The increased ferrous concentration would result in increased sludge production. At sulfide concentrations higher than the 1.0 mg/L sulfide the final turbidity increased. A ferrous feed of 1.0 mg/L ferrous iron with a sulfide feed of 1.0 mg/L sulfide was selected as the optimum concentrations, and the polymer requirements were evaluated with these feed concentrations. The Betz®1195 cationic polymer concentration was evaluated while feeding 0.5 mg/L Betz®1120 anionic polymer. The final solution turbidity after filtering through cotton is shown in Figure 2. The lowest final turbidity was achieved at 20 mg/L Betz®1195, which was used while evaluating the Betz®1120 concentration. The turbidity of the solutions was determined before and after filtering through cotton, and these results are shown in Figures 3 and 4. In both cases, the minimum turbidities occurred at a Betz®1120 concentration ranging from 0.25 to 0.75 mg/L. The optimum Betz®1120 feed concentration was selected as 0.5 mg/L; the final heavy metal concentrations were evaluated at these optimized process reagent concentrations, and the results are shown in Table 7. Table 7 also includes the initial heavy metal concentrations of the sample and the results of treating the waste only with the polymers.

It must be remembered that, although the test using only the polymers showed reduction in the heavy metals concentration, such a treatment would not result in the reduction of the hexavalent chromium if it were present.

TABLE 7. FINAL HEAVY METAL CONCENTRATIONS AFTER OPTIMIZATION FOR CHEMICAL FEEDS.

Sample	1	2	3	4
Cadmium (mg/L)	0.225	0.225	0.755	0.150
Chromium, hexavalent (mg/L)	0.04	0.04	BDL	BDL
Chromium, T (mg/L)	9.000	3.750	0.180	0.075
Copper (mg/L)	0.500	0.250	0.200	0.100
Iron (mg/L)	5.600	4.400	3.000	1.800
Lead (mg/L)	0.400	0.350	0.250	0.175
Nickel (mg/L)	0.190	0.120	0.060	0.055
Phosphorus (mg/L)	5.00	2.25	2.12	0.88
Zinc (mg/L)	0.450	0.400	0.200	0.175
COD (mg/L)	815	650	640	
Turbidity (FTU)	140	124	8	10
pH	6.5	6.5	7.5	7.6

Sample Identification

1. Sample collected from CAFB CCF December 17, 1991.
2. Sample collected from CAFB CCF December 17, 1991, after filtering through Whatman #4 filter paper.
3. Sample treated by sodium sulfide/ferrous sulfate process, but with no prior organic treatment.
4. Sample treated by polymer addition only.

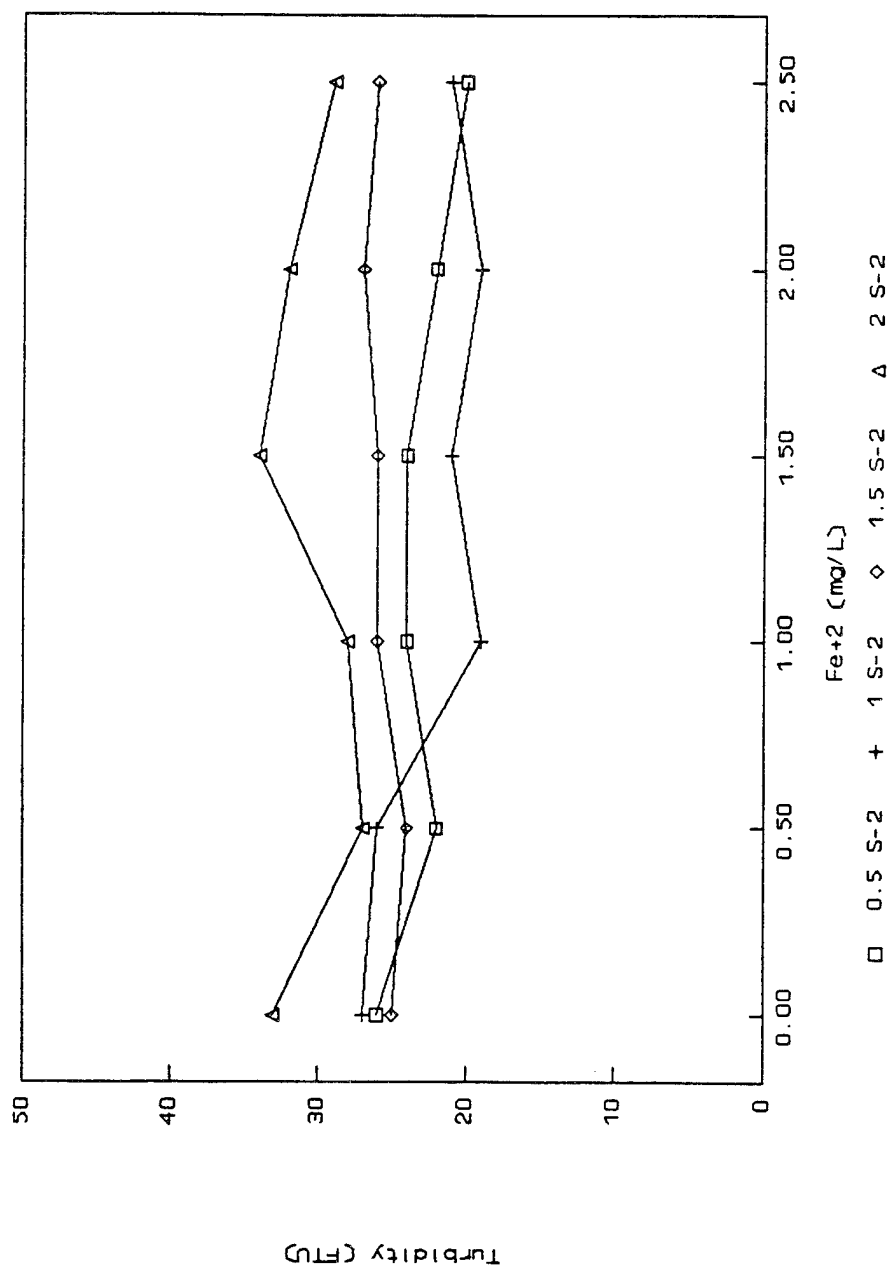


Figure 1. CAFB Wastewater Final Solution Turbidity as a Function of the Ferrous Iron Concentration at Fixed Sulfide Feed Concentrations.

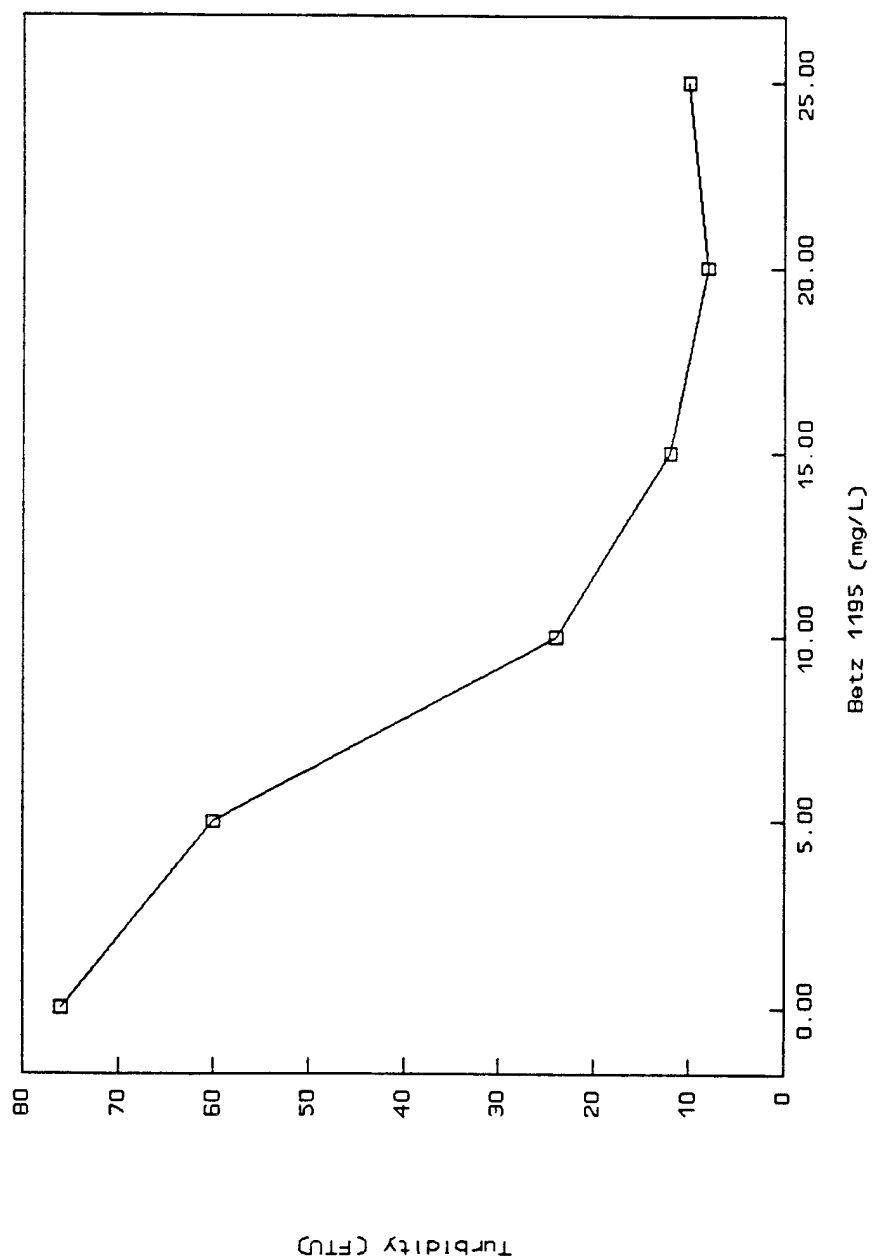


Figure 2. CAFB Wastewater Final Turbidity as a Function of the Betz®1195 Feed Concentration.

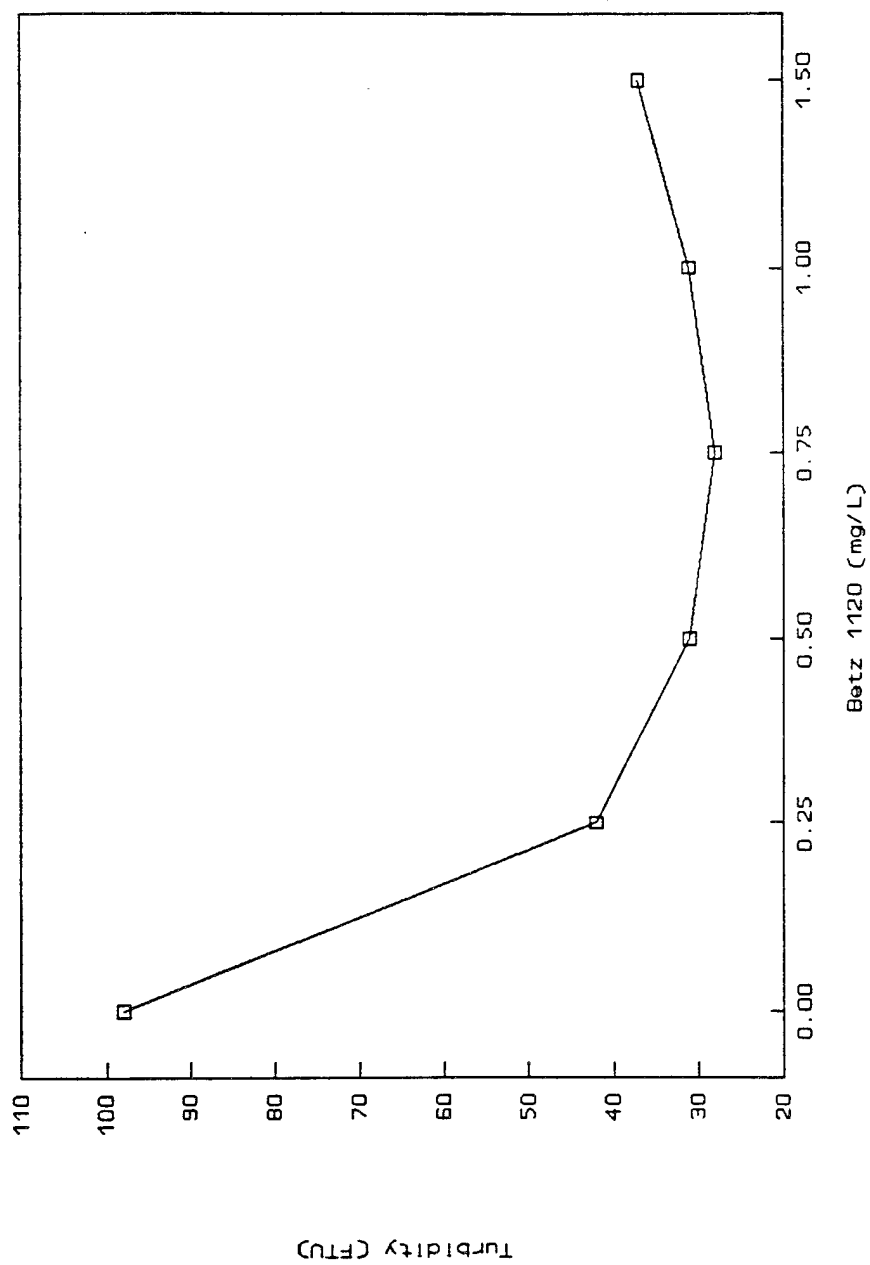


Figure 3. CAFB Wastewater Final Solution Turbidity prior to Filtering through Cotton as a Function of the Betz®1120 Feed Concentration.

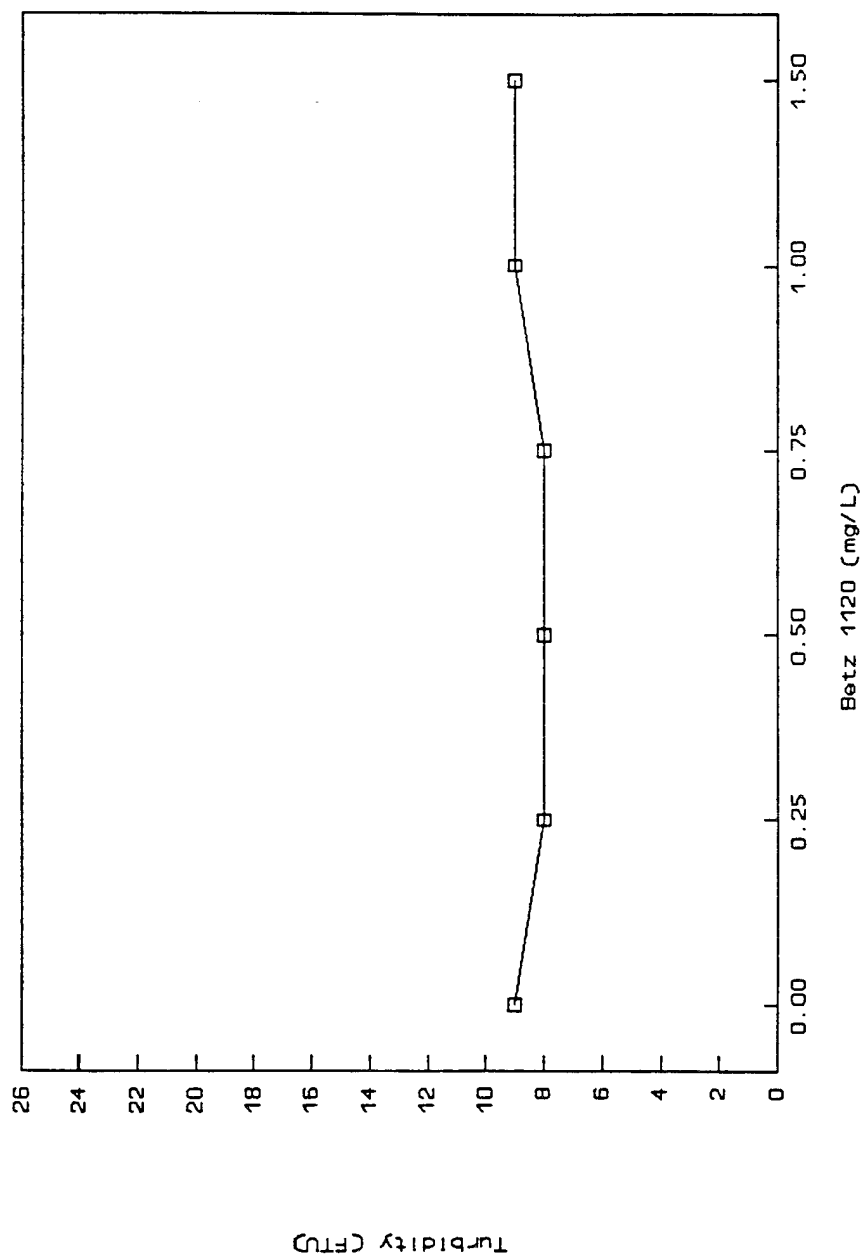


Figure 4. CAFB Wastewater Final Solution Turbidity after Filtering through Cotton as a Function of the Betz®1120 Feed Concentration.

3. Organic Treatment

The wastewater from the CCF at CAFB contained both heavy metals and TTO concentration above discharge requirements for the domestic sewage treatment plant of the base. The sodium sulfide/ferrous sulfate process is only applicable for metal removal and cannot be used for toxic organic treatment. Consequently, a study was performed to find an organic treatment technique applicable to the CCF wastewater.

Several types of organic treatment methods are commercially available, including chemical oxidation, adsorption, and biological treatment. Because of the concentration of organic compounds in the CCF wastewater and the requirement for batch treatment, chemical oxidation and subsequent treatment with carbon polishing was determined to be the most efficient treatment process. Carbon polishing is suggested as a secondary method for removal of the TTO if, due to changes in the constituents or constituent concentration, the TTO are not completely oxidized by the chemical oxidation method.

The chemical oxidation methods reviewed included oxidation with hydrogen peroxide in the presence of a catalyst (Fenton process), oxidation with potassium permanganate, wet air oxidation, incineration, and ozonation. Each process was reviewed; the evaluations appear in Appendix G.

The two chemical oxidation processes that appeared to be best suited for treating the CAFB CCF wastewaters and coupling to the sodium sulfide/ferrous sulfate metal treatment process were the Fenton process and ozonation/oxidation with the Brinecell® electrolysis process. These processes are most suited for the organic concentrations of the wastewater and batch- or short-term operation. Carbon polishing was evaluated as an option for a final organic removal process after chemical oxidation to reduce the COD concentration.

a. Evaluation of the Fenton Process

The results of the evaluation of the Fenton process on wastewater from the CCF are shown in Figures 5 through 8. Figure 5 shows the results of varying the hydrogen peroxide concentration with a fixed ferrous addition of 200 mg ferrous iron/L of wastewater. The effect of varying the hydrogen peroxide concentration and maintaining a ratio of 10 mg hydrogen peroxide per one mg ferrous iron is shown on the same graph. The final COD concentration decreased with increasing hydrogen peroxide concentrations for both cases with the final COD concentration being 100 mg/L. The increase from 2,000 mg/L hydrogen peroxide to 8,000 mg/L hydrogen peroxide did not result in a large change in the final COD concentration. Figure 6 shows the effect of varying the iron concentration while adding 6,000 mg hydrogen peroxide per liter of wastewater to each test. At 200 mg/L iron, the COD is decreased to 100 mg/L; further increase in the iron concentration does not decrease the COD concentration. Varying the hydrogen concentration at a fixed ferrous iron concentration of 200 mg/L and allowing a 24-hour reaction period

resulted in a final COD concentration of approximately 50 mg/L (Figure 7). Increasing the iron (Figure 8) did not result in any further decrease in the final COD concentration. Appendix C lists the data for the evaluation of the Fenton process.

The Fenton process was further evaluated as shown in Figures 9 through 11. Further testing on the same wastewater showed that increasing the hydrogen peroxide to greater than 2,000 mg/L (2 mg hydrogen peroxide per one mg COD in the wastewater) did not result in a significant decrease in the final COD concentration (Figure 9) nor did increasing the ferrous iron concentration (Figure 9 and 10). However, decreasing the ferrous iron concentration to 125 mg/L as shown in Figure 11 did result in an increase in the final COD concentration; little change occurred in the final COD concentration when the ferrous iron concentration was varied between 150 and 250 mg/L.

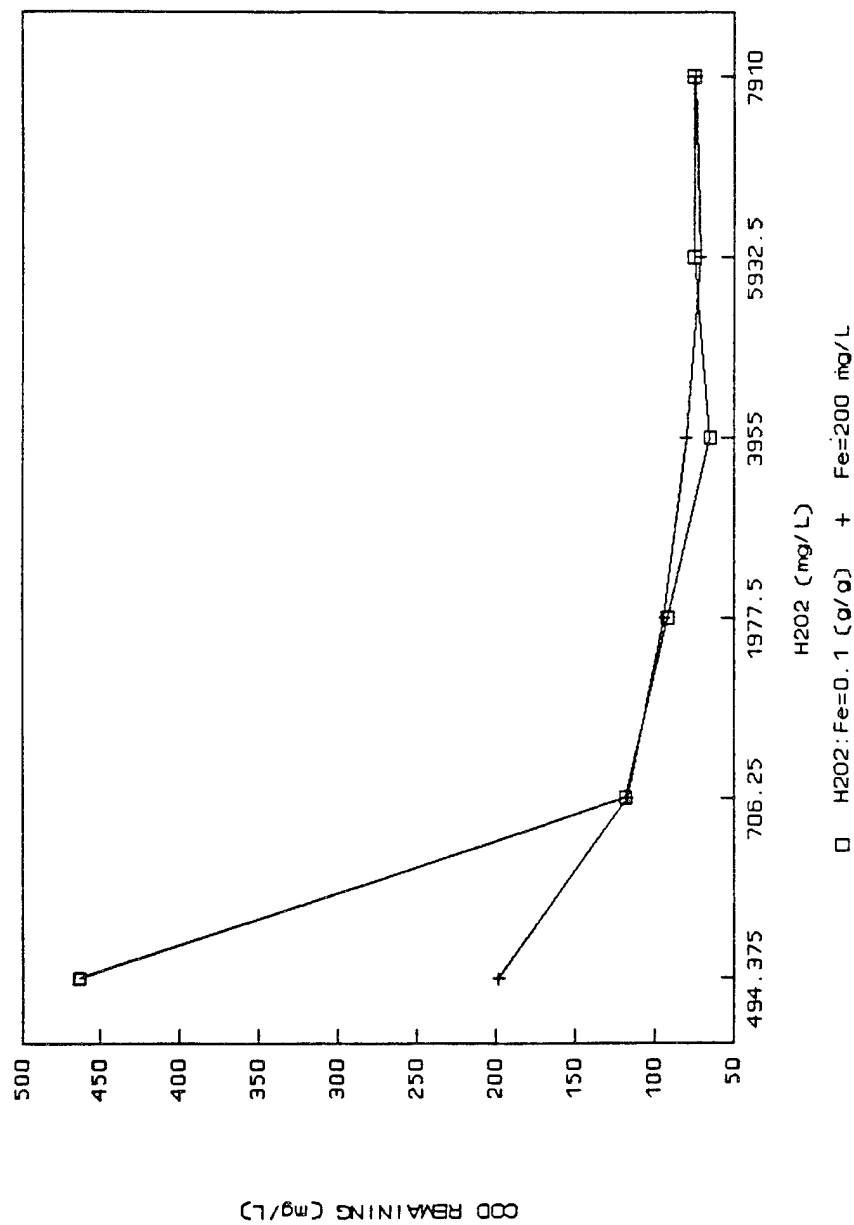


Figure 5. COD Remaining after Treatment of the CAFB Wastewater with Fenton Reagent as a Function of Hydrogen Peroxide Concentration.

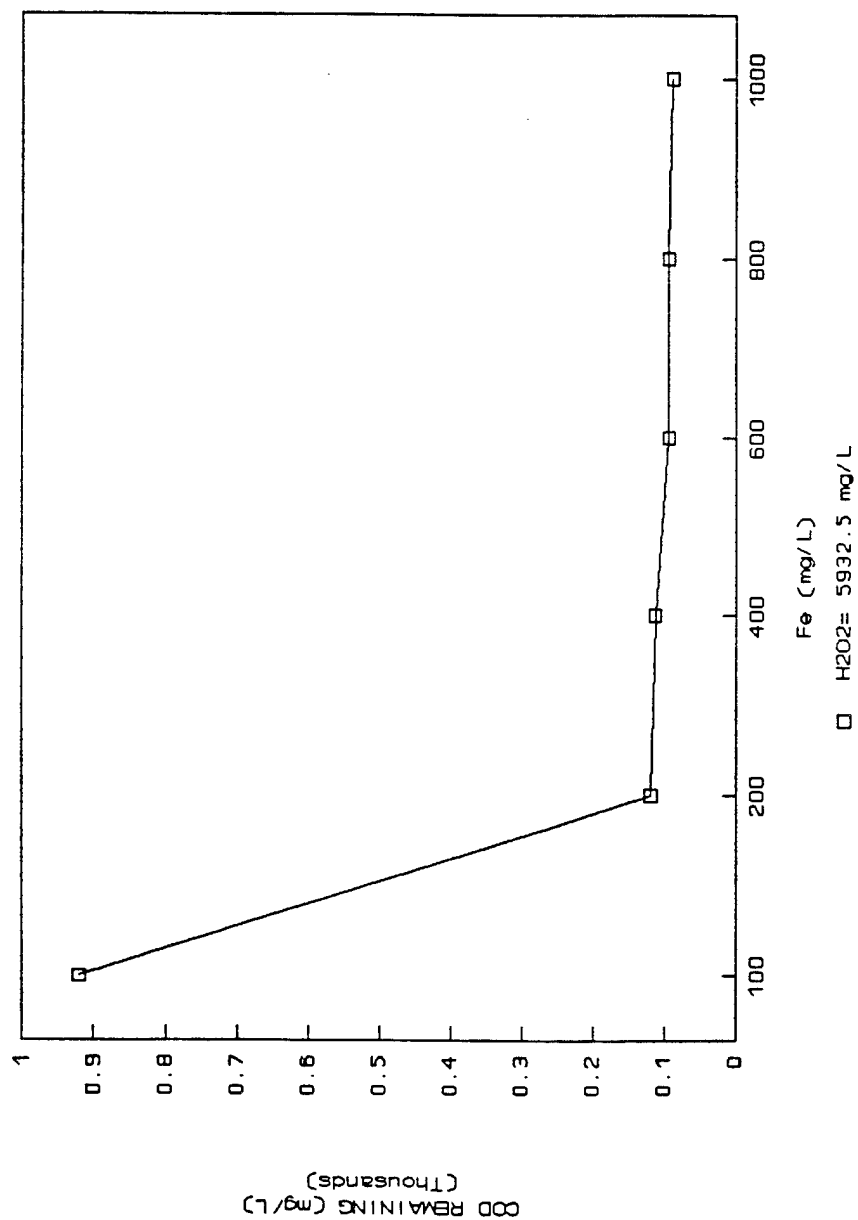
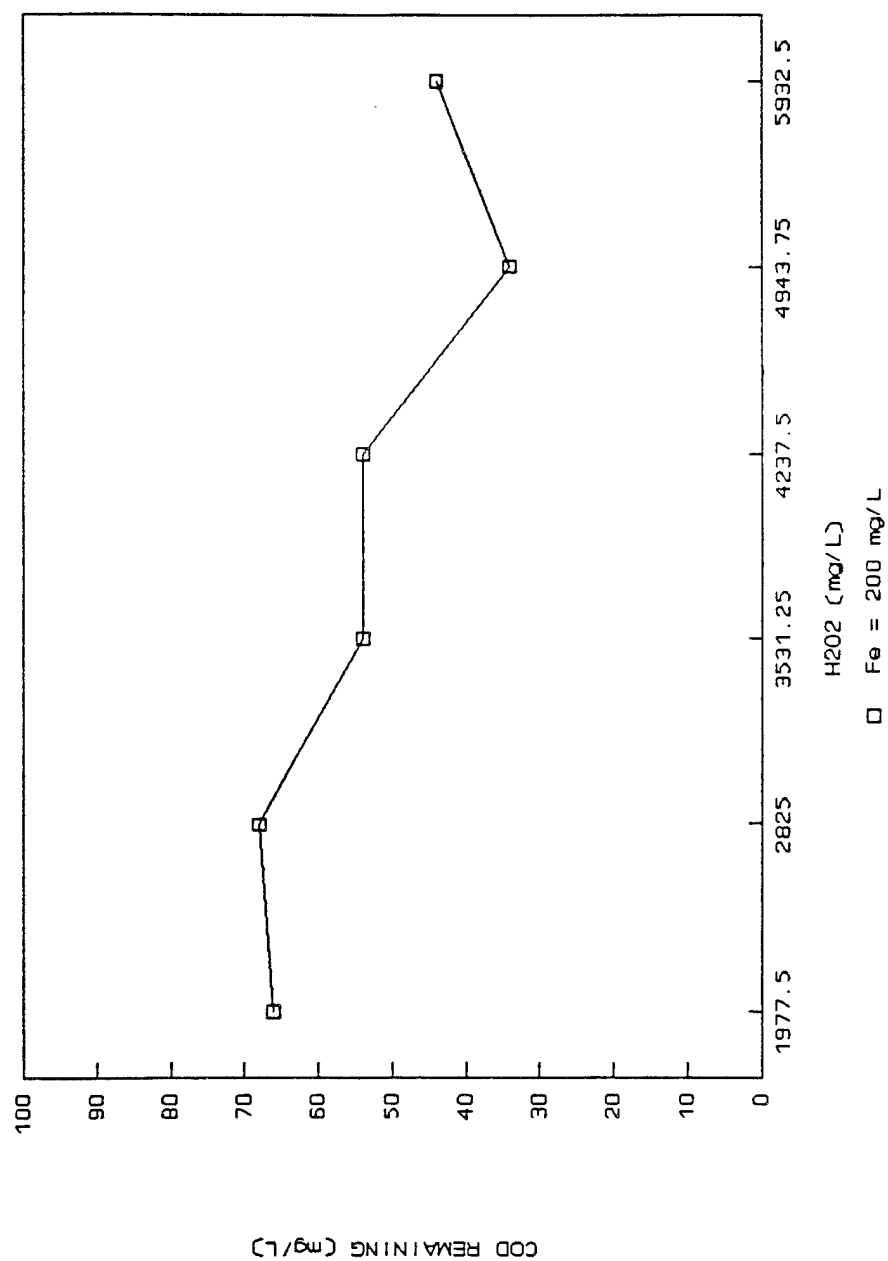


Figure 6. COD Remaining after Treatment of CAFB Wastewater with Fenton Reagent as a Function of Ferrous Iron Concentration.



Figure, 7. COD Remaining after Treatment of CAFB Wastewater with Fenton Reagent for 24 Hours as a Function of the Hydrogen Peroxide Concentration.

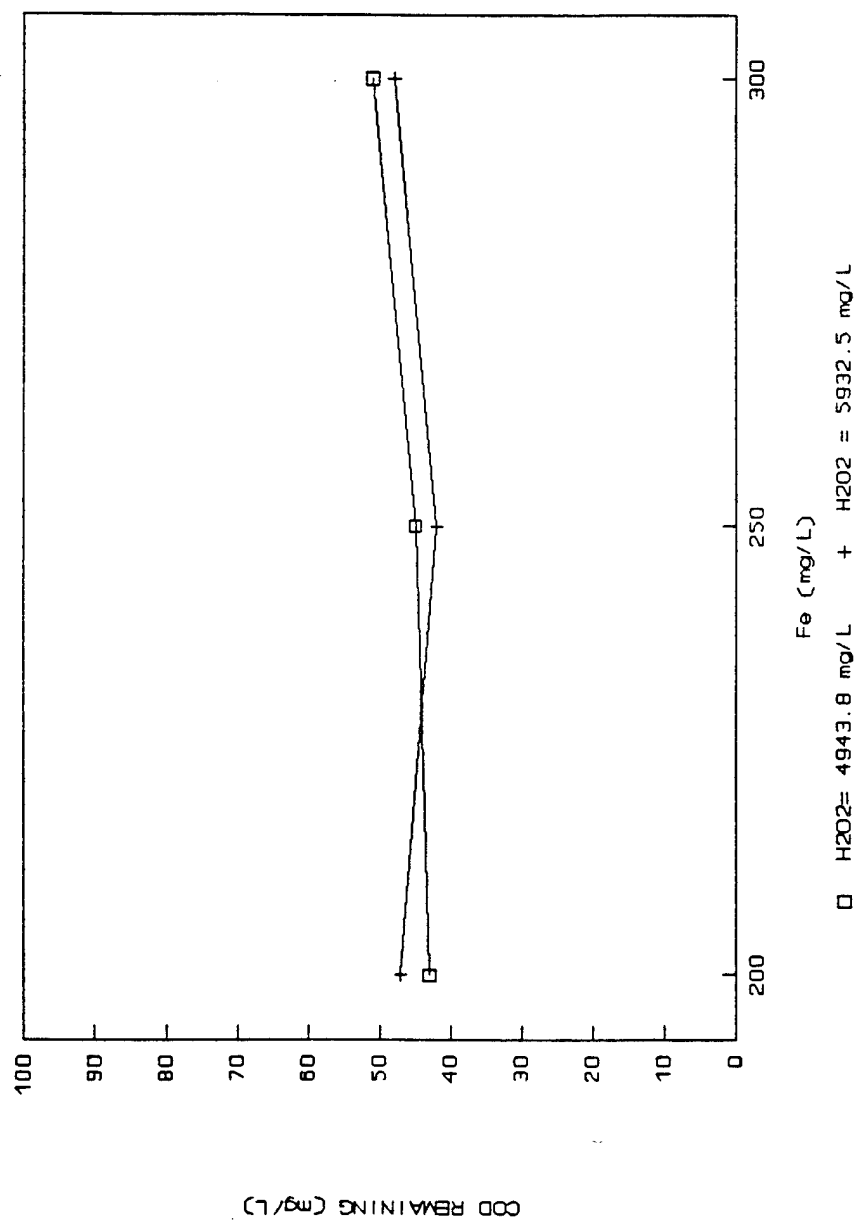


Figure 8. COD Remaining after Treatment of CAFB Wastewater with Fenton Reagent for 24 Hours as a Function of the Ferrous Concentration.

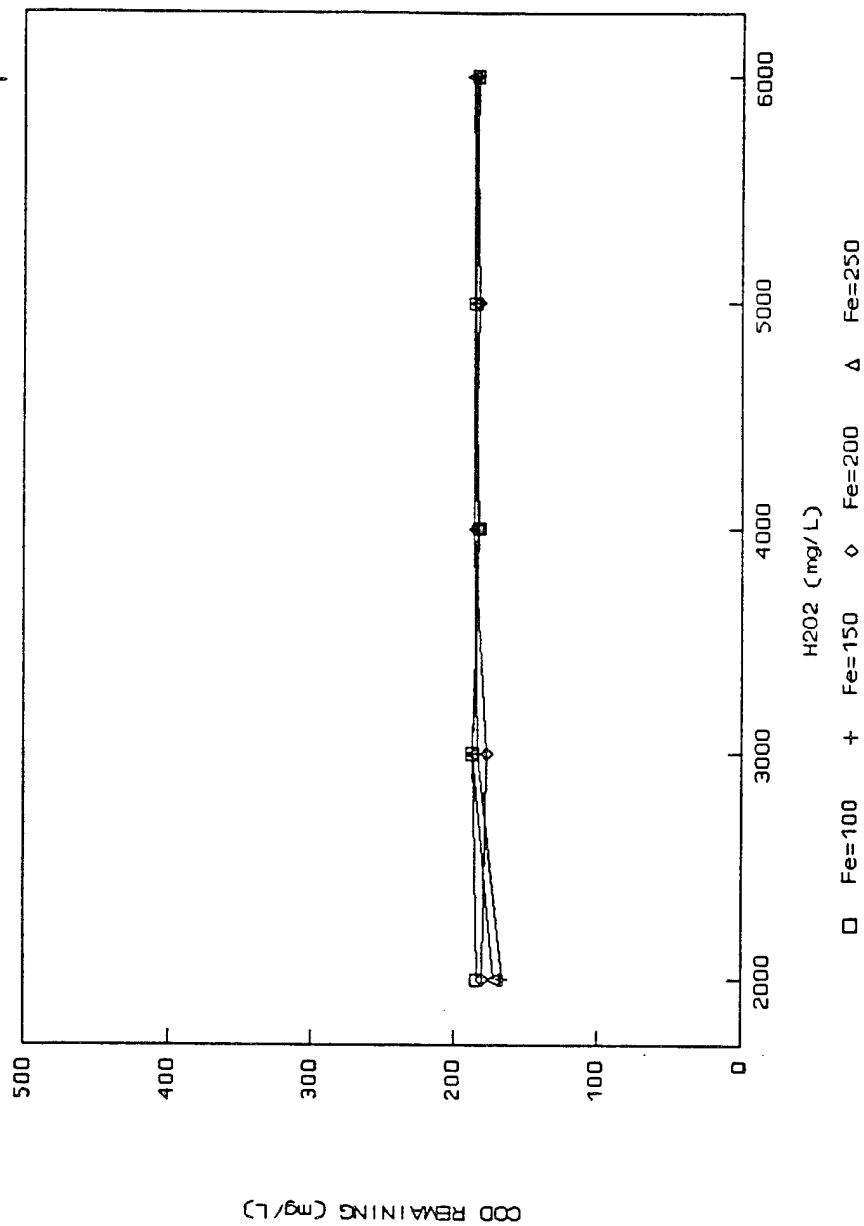


Figure 9. COD Remaining after Treatment of CAFB Wastewater with Fenton Reagent as a Function of the Hydrogen Peroxide Addition at Fixed Additions of Ferrous Iron.

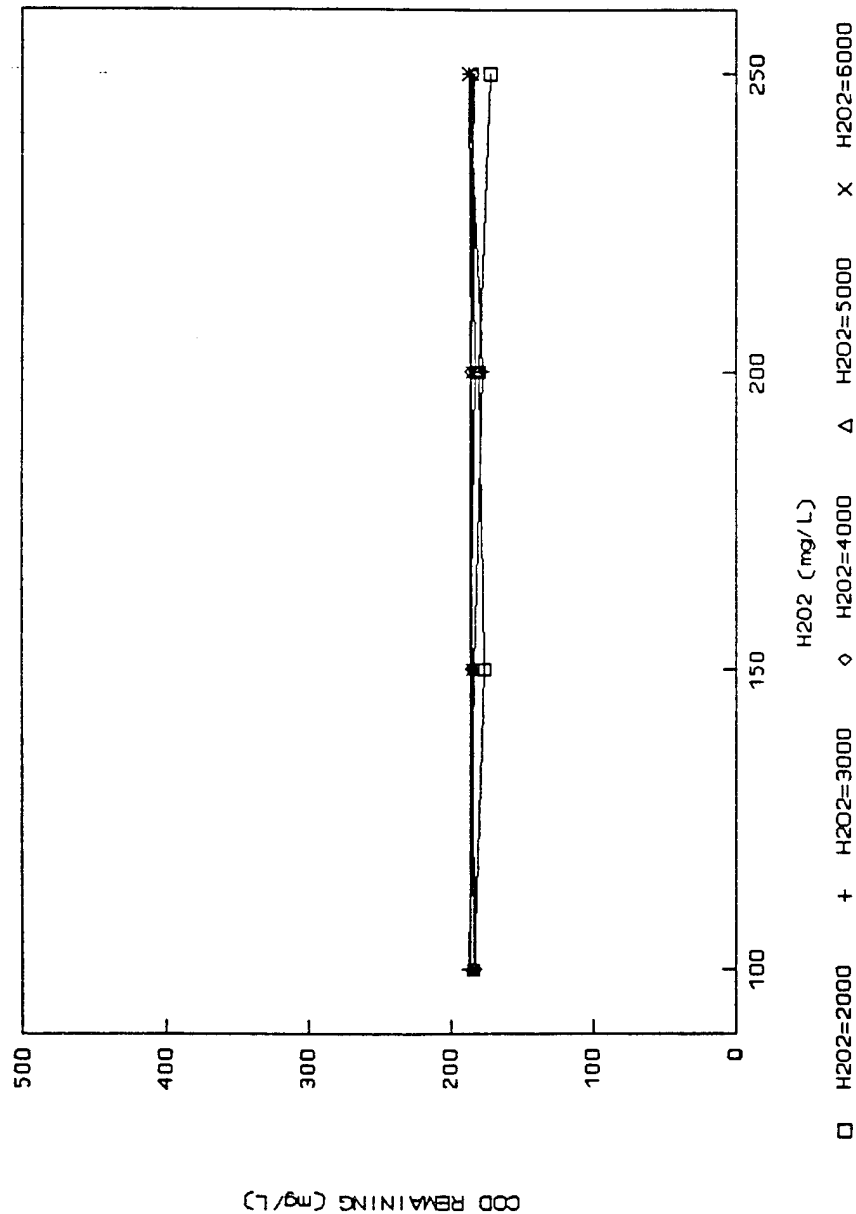


Figure 10. COD Remaining after Treatment of CAFB Wastewater with Fenton Reagent as a Function of the Ferrous Iron Addition at Additions of Hydrogen Peroxide.

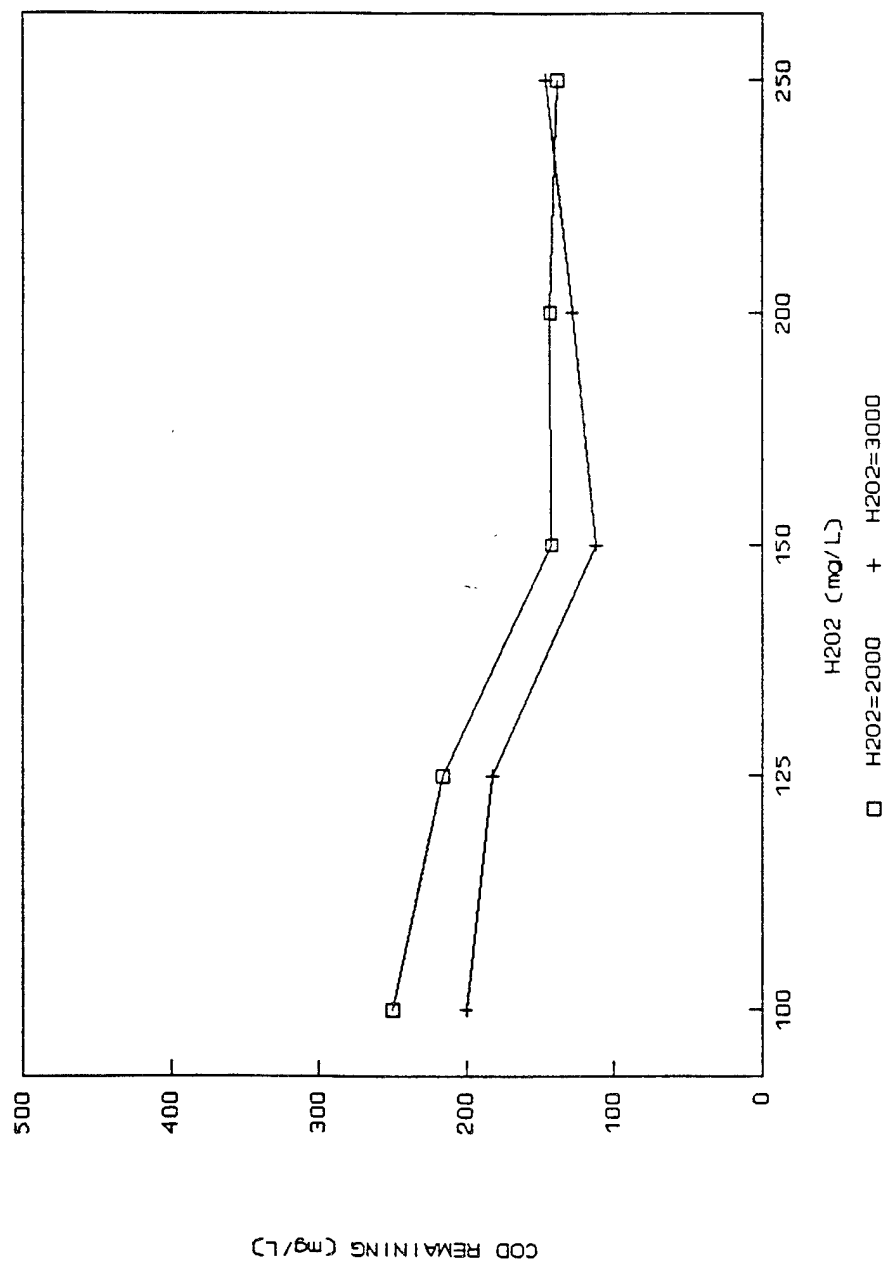


Figure 11. COD Remaining after Treatment of CAFB Wastewater with Fenton Reagent as a Function of the Ferrous Iron Concentration with the Addition of 2,000 and 3,000 mg/L of Hydrogen Peroxide.

These tests resulted in the selection of the hydrogen peroxide feed ratio of two mg hydrogen peroxide to treat one mg COD and the ferrous iron concentration at 0.2 mg to treat one mg COD or at one-tenth the hydrogen peroxide concentration.

The requirements to achieve metal removal from the wastewater treated by the Fenton process was determined, and Tables 8 and 9 present the results of testing to define the sulfide and ferrous concentration required for heavy metal removal. Table 9 also presents a comparison of the sulfide precipitation process to precipitation with caustic. There was no detectable hexavalent chromium present in the wastewater sample available from CAFB, although 10 mg/L of hexavalent chromium was added to the sample prior to treatment with the Fenton reagent for removal of organic compounds. The chromium was completely reduced by the end of the organic treatment process. This reduction is due to the presence of the ferrous sulfate at the low pH; however, it is conceivable that a sample will contain hexavalent chromium at the completion of the organic treatment process. This could occur in the case where high hexavalent chromium is present initially or the wastewater contains a low concentration of organics which would require a smaller addition of the ferrous iron during the organic treatment process.

TABLE 8. THE EFFECT OF SULFIDE AND FERROUS ADDITION ON THE CHROMIUM REDUCTION AND THE FINAL SOLUTION TURBIDITY AFTER TREATMENT WITH FENTON REAGENT FOR CHEMICAL OXYGEN DEMAND REMOVAL.

Test	Initial Cr ⁺⁶ (mg/L)	S ⁻² (mg/L)	Fe ⁺² (mg/L)	Betz®1195 (mg/L)	Betz®1195 (mg/L)	Turbidity (FTU)	Final Cr ⁺⁶ (mg/L)
1	0.00	1.5	0.0	10	0.5	4	0.00
2	0.00	2.0	0.0	10	0.5	3	0.00
3	0.00	2.5	0.0	10	0.5	0	0.00
4	0.00	3.0	0.0	10	0.5	7	0.00
5	0.00	3.5	0.0	10	0.5	14	0.00
6	10.0	12.5	0.0	10	0.5	25	8.50
7	10.0	18.8	0.0	10	0.5	21	0.26
8	10.0	25.0	0.0	10	0.5	19	0.18
9	10.0	31.3	0.0	10	0.5	16	0.11
10	10.0	37.5	0.0	10	0.5	13	0.06
11	10.0	13.3	20.0	10	0.5	17	5.00
12	10.0	20.0	20.0	10	0.5	11	2.75
13	10.0	26.6	20.0	10	0.5	10	1.00
14	10.0	33.3	20.0	10	0.5	0	0.03
15	10.0	39.9	20.0	10	0.5	1	0.03
16	10.0	35.0	25.0	10	0.5	1	0.00

Optimum effluent turbidity [Turbidity = 0 Federal Turbidity Unit (FTU)] occurred with the addition of 2.5 mg/L sulfide when no hexavalent

TABLE 9. EFFLUENT WASTEWATER QUALITY AFTER TREATMENT WITH 2.5 MG/L SULFIDE VERSUS TREATMENT WITH CAUSTIC AT PH 8.5.										
Sample	Ni (mg/L)	Zn (mg/L)	P (mg/L)	COO (mg/L)	Cd (mg/L)	Cr ⁺⁺ (mg/L)	Cr (mg/L)	Cu (mg/L)	Fe (mg/L)	Pb (mg/L)
Discharge Requirements Monthly Average	3.98	2.61			0.11		2.77	3.38		0.69
Discharge Requirements Daily Maximum	2.38	1.48			0.07		1.77	2.07		0.43
Raw Sample 7/09/91	0.03	0.50	26.25	1100	0.55	0.01	4.79	0.30	7.9	0.45
Raw Sample 7/09/91 Filtered	0.01	0.40	19.06	600	0.40	0.01	2.92	0.28	2.5	0.25
Treated for COO and with 2.5 mg/L Sulfide	0.05	0.35	3.13	47	0.08	BDL	0.03	0.05	0.8	0.02
Treated for COO and pH Adjusted with Caustic to 8.5	0.03	0.25	4.00	47	0.08	BDL	0.03	0.15	0.9	0.08

chromium was present in the wastewater after organic removal; additional ferrous was not required. Hexavalent chromium reduction to below detection required the addition of 35 mg/L sulfide and 25 mg/L ferrous iron when 10 mg/L hexavalent chromium was added to the wastewater after the organic treatment process (Figure 12). This is a ratio of 3.5 mg/L sulfide and 2.5 mg/L ferrous iron per one mg/L hexavalent chromium. Chromium reduction was achieved to 0.03 mg/L with the addition of 3.3 mg/L sulfide and two mg/L ferrous iron, and although this would meet the water quality requirement, past experience has shown it is better to treat the hexavalent chromium to below detection, which results in a wastewater of lower effluent turbidity and subsequently lower effluent heavy metals concentrations.

Polymer evaluations were not conducted other than at 10 mg/L Betz®1195 cationic polymer addition and 0.5 mg/L Betz®1120 anionic polymer addition. These chemical concentrations were consistent with the requirements during testing at Pensacola Public Works Center and Tinker AFB. Upgrading to pilot scale has sometimes required some additional polymer, but jar testing would normally not show this requirement.

A sample of wastewater that had been treated by the Fenton process and sodium sulfide/ferrous sulfate metal precipitation process was submitted to Analytical Technologies Inc., for TTO analysis. No TTOs were detected in this sample.

b. Evaluation of the Brinecell®

The Brinecell® process uses an electrode to create hydrogen peroxide, ozone, and chlorine to oxidize the organics present in the wastewater; this oxidation is dependent on the salt (sodium chloride, NaCl) concentration and the organic compounds being oxidized. A laboratory unit was leased to evaluate the process. Data from this evaluation are shown in Appendix D. Increasing the salt concentration to 10 g/L sodium chloride resulted in a reduction of the COD (Table 10). However, increasing the salt

TABLE 10. CHEMICAL OXYGEN DEMAND REDUCTION AS A FUNCTION OF THE SALT CONCENTRATION ON AN UNDILUTED SAMPLE OF CAFB WASTEWATER.				
Sample Volume (mL)	NaCl (g/L)	pH	Duration (min)	COD (mg/L)
2,000	1	6-7	60	1,000
2,000	2	6-7	60	1,040
2,000	3	6-7	60	960
2,000	4	6-7	60	590
2,000	10	6-7	60	40

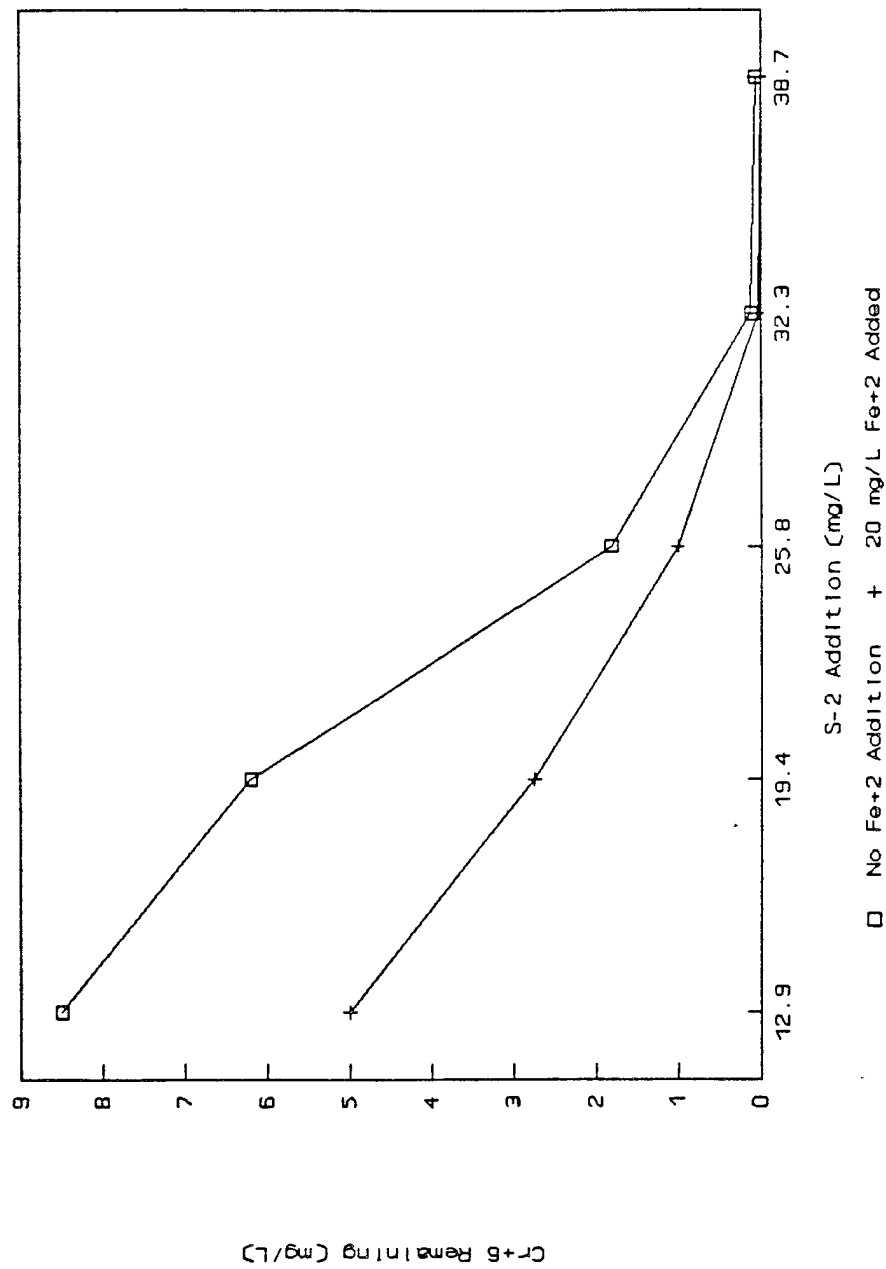


Figure 12. Hexavalent Chromium Reduction as a Function of the Sulfide Addition with and without Ferrous Addition for CAFB Wastewater Treated by the Fenton Process.

to this concentration, resulted in an increase in the current and an increase in the temperature of the wastewater in the test vessel. Figure 13 shows the decrease in COD as a function of time for an undiluted sample of CAFB wastewater. After 120 minutes, the COD had decreased to 0, but, as shown in Figures 14 and 15, the temperature had increased to 90 °C and the current to about 16 amps. Figure 16 shows the same test run with the temperature controlled between 20 and 40 °C, the COD decreased to approximately 350 mg/L after one hour. In comparing the test results, it is assumed the low COD as shown in Figure 13 and Table 10 is due to the increased temperature and volatilization of the COD. Further testing was conducted with the temperature controlled; however, because the small size of the laboratory model, increasing the salt concentration to greater than 10 g/L resulted in such an increase in temperature that temperature control was not possible. Therefore, treating dilutions of the wastewater with lower concentrations of salt were evaluated.

To control the temperature, the evaluation was conducted using a 1-to-10 dilution of CCF wastewater. Figure 17 shows the COD remaining as a function of time as the salt concentration is varied. The COD was reduced from 110 mg/L to near zero in less than 30 minutes with one g/L of sodium chloride; increasing the salt concentration to two g/L did not further decrease the time required to achieve the low COD concentration.

c. Carbon Polishing

Although the wastewater treated by the Fenton process and the sodium sulfide/ferrous sulfate process did not contain TTOs, the addition of an activated polishing unit to the treatment unit for this wastewater would provide protection against discharge of wastewaters that did not meet the TTO discharge requirements. This could occur if the Fenton process did not go to completion or compounds were present that were resistant to chemical oxidation. An added benefit of the addition of carbon polishing could be reduction of the COD to a concentration where COD monitoring would serve to demonstrate TTO requirements are being met. This could eliminate the need for expensive TTO analysis before disposal of the treated wastewater.

Activated carbon samples were received from two corporations that sell activated carbon: 1) TIGG 5D 1240 Virgin Activated Carbon (pulverized) from Tigg Corporation and 2) Darco Activated Carbon HD4000 Batch 42-91 from American Norit Company, Inc. The carbon was evaluated, using the CAFB sample that had been collected in June, and the results of the tests are shown in Figures 18 and 19. Sample 6 of each set was analyzed for heavy metals. In addition, the wastewater was

analyzed for heavy metals after treatment with the Fenton process and heavy metal removal with the sodium sulfide/ferrous sulfate process. The data from the metal analysis is shown in Table 11. The activated carbon sample from Tigg Corporation is a fine pulverized powder; this sample removed the COD to a concentration of 68 mg/L. The sample from Norit Company is a granular activated carbon; this sample removed the COD to a concentration of 80 mg/L. It is expected that a powder carbon will result in greater COD removal per weight of carbon due to the increased surface area.

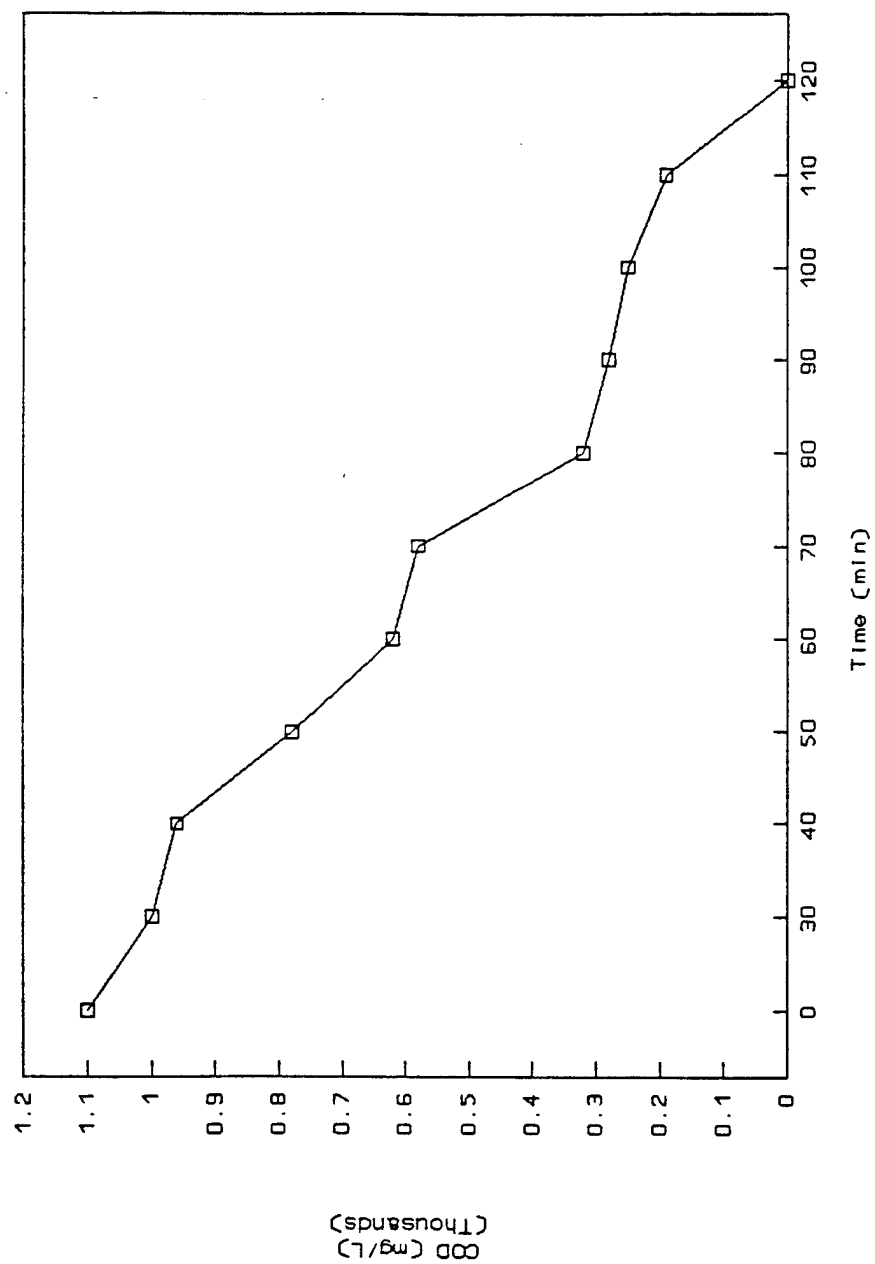


Figure 13. COD Reduction of CAFB Wastewater with the Brinecell® Process with 10 g/L NaCl with the Temperature Allowed to Increase.

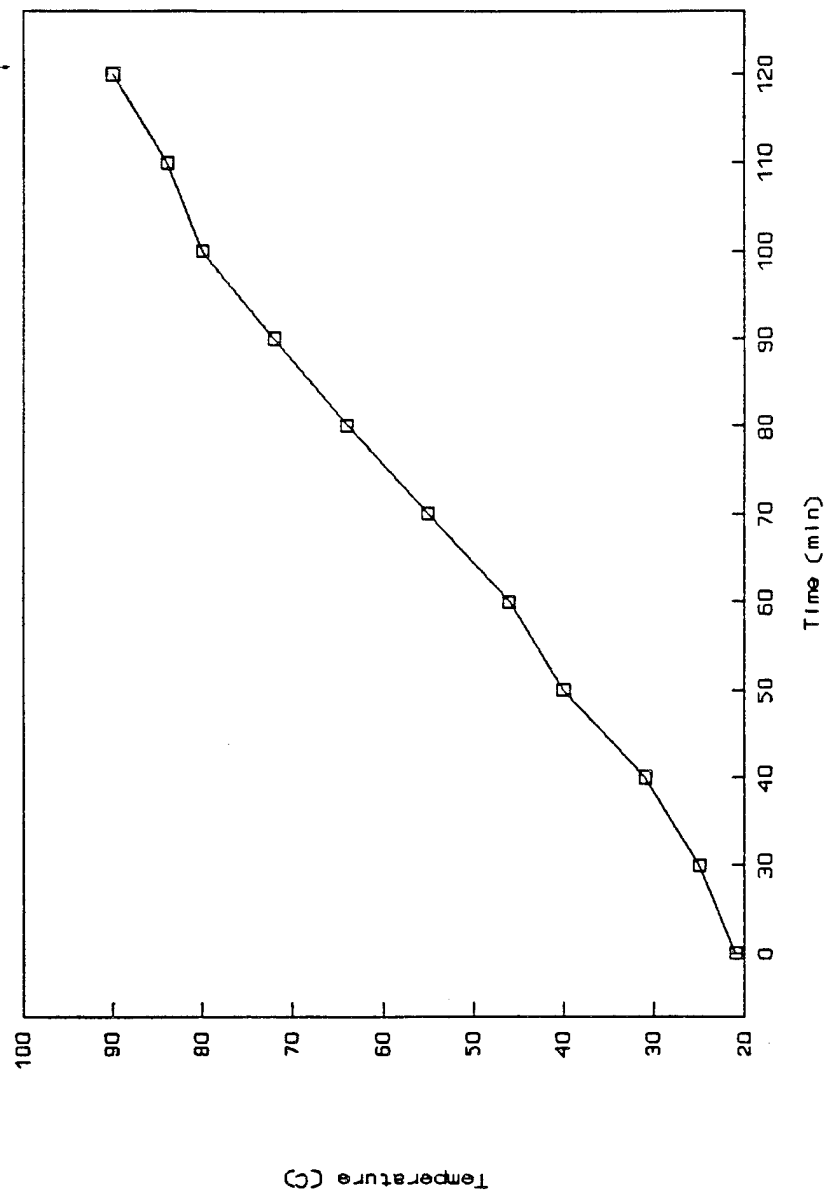


Figure 14. Temperature as a Function of Time in the Brinecel' Test.

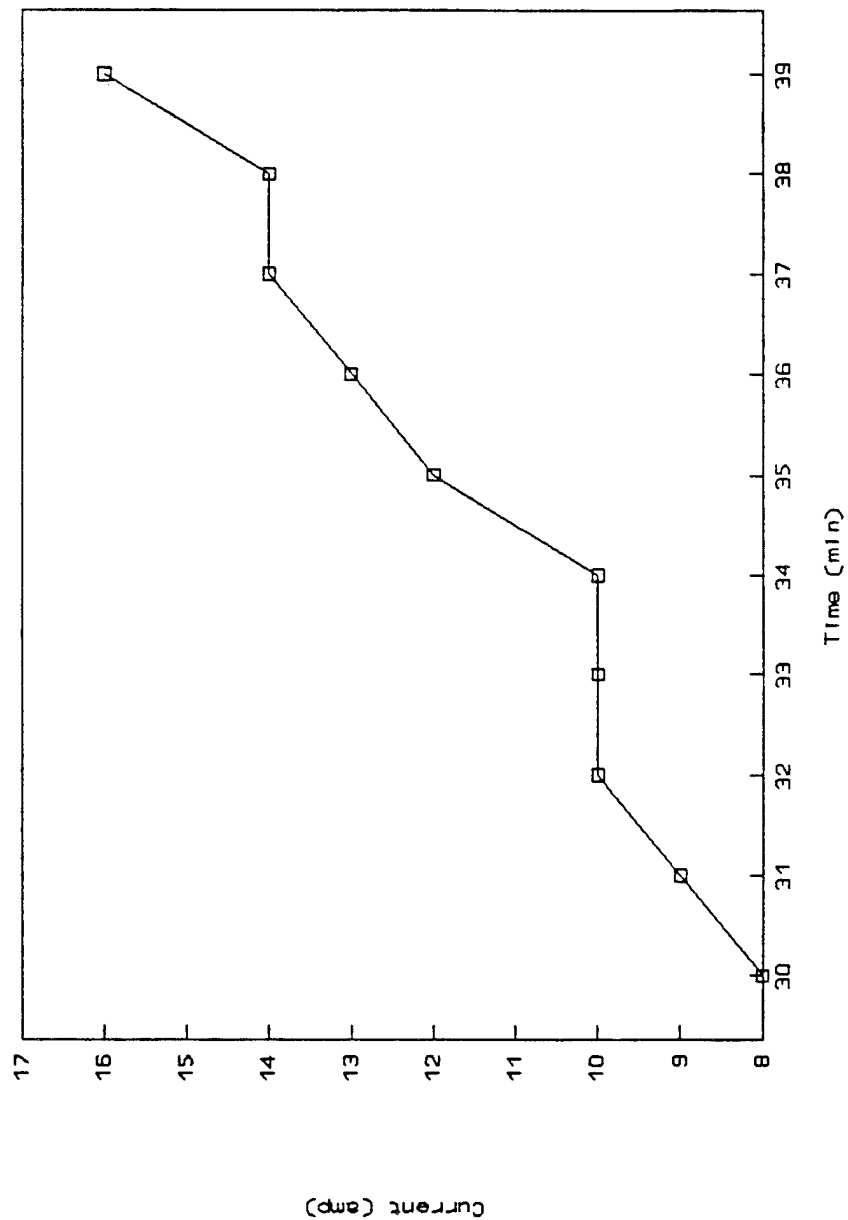


Figure 15. Current as a Function of Time in the Brinecell® Test.

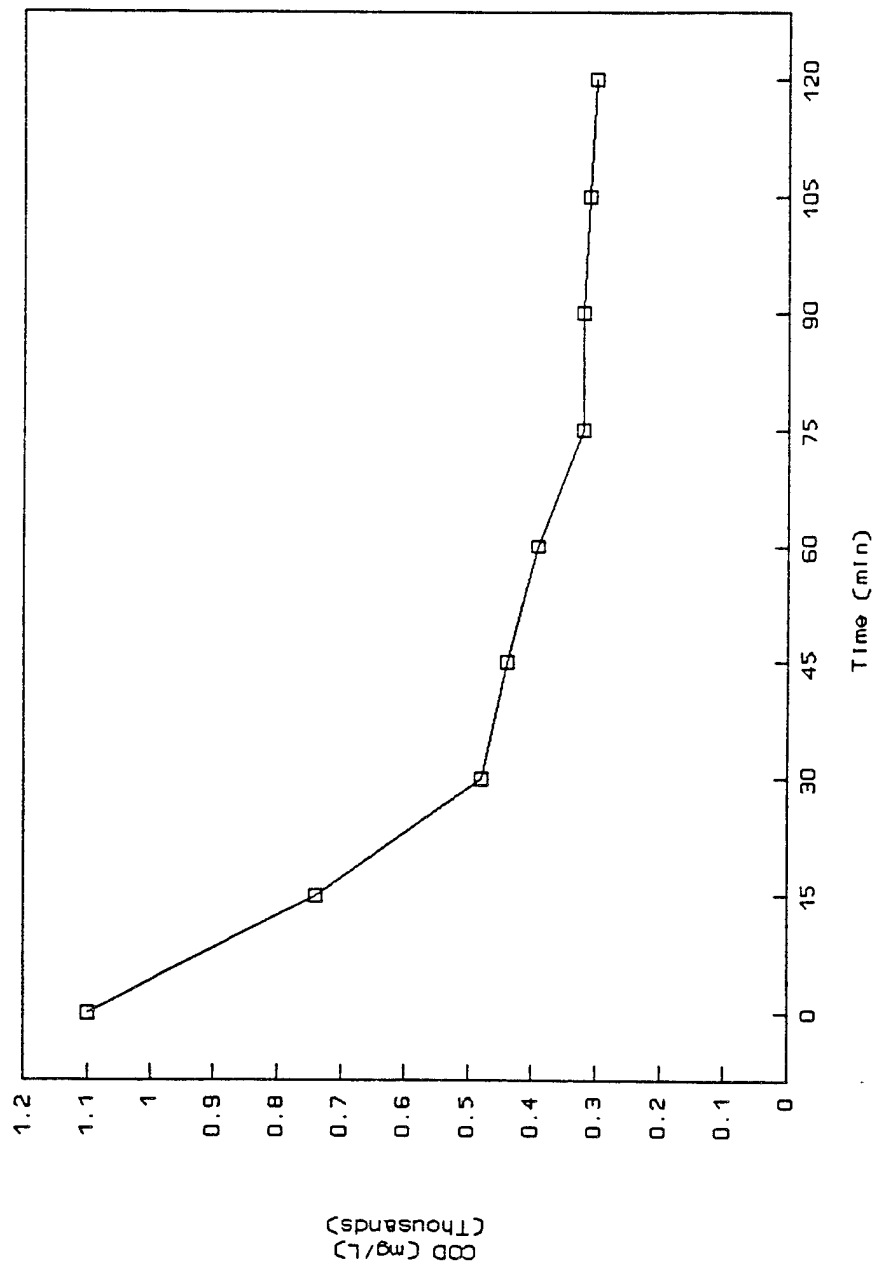


Figure 16. COD Reduction of CAFB Wastewater as a Function of Time after Treatment with the Brinecello Process at Fixed Temperature.

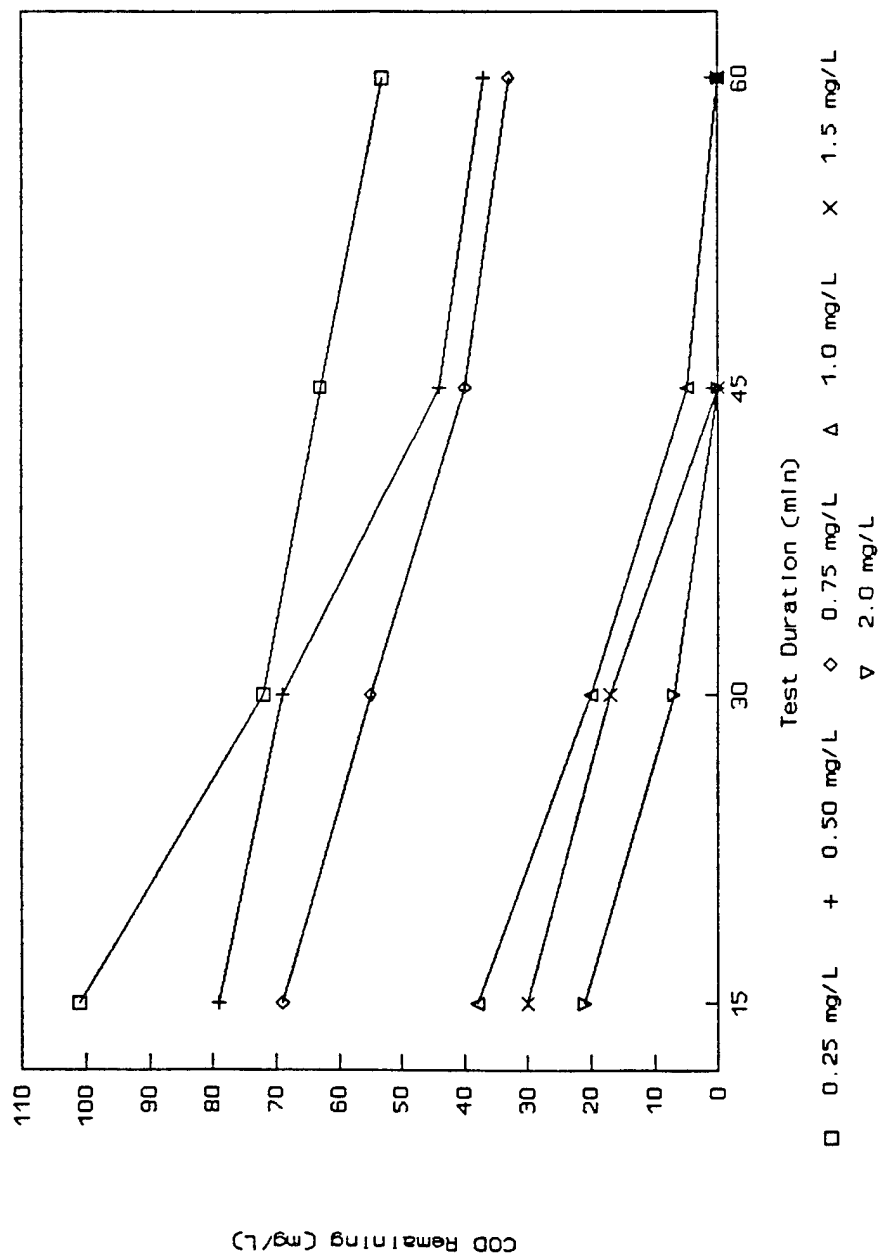


Figure 17. The Effect of Increasing Salt Concentration on the COD Reduction as a Function of Time with a 1:10 Dilution of the CAFB Wastewater.

TABLE 11. HEAVY METAL REMAINING AFTER TREATMENT WITH ACTIVATED CARBON
(TEST SERIES 1).

	Sample 1	Sample 2	Sample 3
Cd (mg/L)	0.048	0.010	0.019
Cr ⁺⁶ (mg/L)	BDL	BDL	BDL
Cr (mg/L)	0.225	0.021	0.066
Cu (mg/L)	0.098	0.009	0.026
Fe (mg/L)	0.106	0.041	0.085
Pb (mg/L)	0.114	0.029	0.055
Ni (mg/L)	0.053	0.025	0.031
Zn (mg/L)	0.148	0.018	0.029

Sample Identification:

1. Sample after treatment with the Fenton process and the sodium sulfide/ferrous sulfate process.
2. Sample 1 after treatment with Tigg powder carbon.
3. Sample 1 after treatment with Norit carbon.

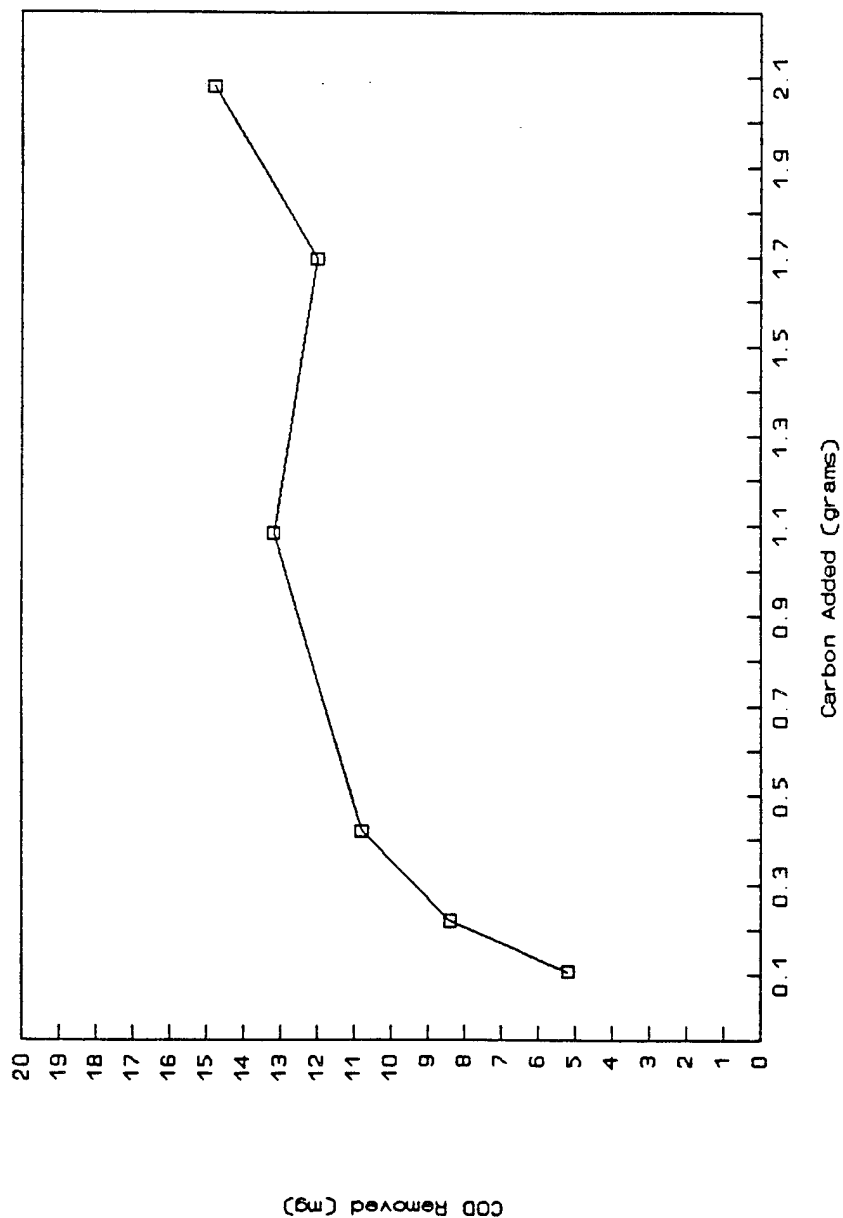


Figure 18. COD Removal from CAFB Wastewater after Treatment for Organic and Metal Removal Using a Sample of Activated Carbon from Tigg Corporation.

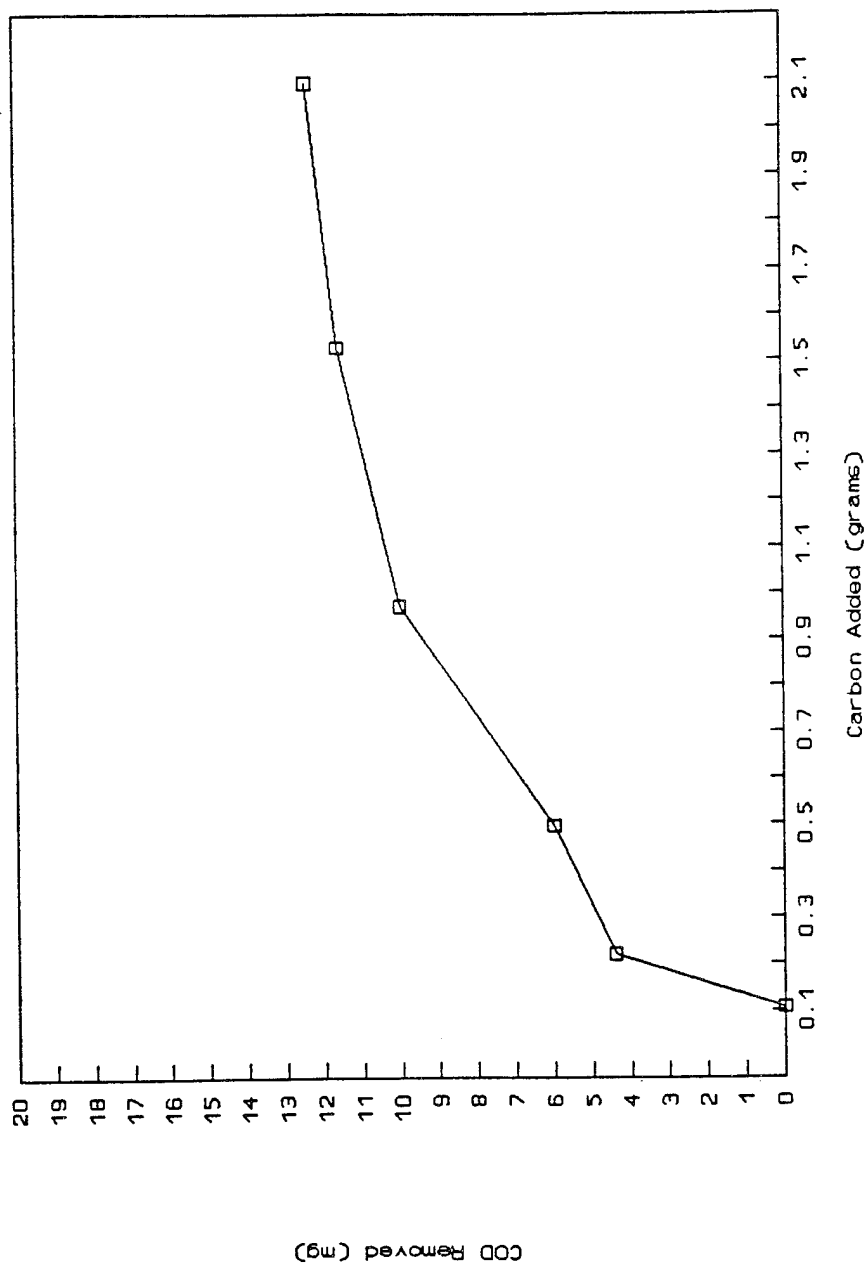


Figure 19. COD Removal from CAFB Wastewater after Treatment for Organic and Metal Removal Using a Sample of Carbon from Norit Corporation.

The carbon was further evaluated on a sample of wastewater treated with the sodium sulfide/ferrous sulfate process at the optimum sulfide and ferrous concentrations (Figures 20 and 21) and also on a sample of wastewater treated with the Fenton process and sodium sulfide/ferrous sulfate process (Figures 22 and 23). Heavy metal analysis was conducted on two samples treated with the largest volume of carbon of Figures 20 and 21; the data is presented in Table 12. In all cases, there seems to be a limit to the final COD removal from the solutions. The Norit granular carbon resulted in the greatest COD removal at 25 grams of carbon for a 150 milliliter sample, and the plot of the COD removal as a function of the carbon added is nearest to what is to be expected in evaluating the carbon for carbon polishing (Figure 22). The plot of the data from the Tigg Carbon (Figure 23) flattens with increased carbon indicating that increased carbon addition will not further increase the COD removal. The data from evaluation of carbon polishing is given in Appendix E.

TABLE 12. SAMPLE ANALYSIS AFTER CARBON EVALUATION TESTS (TEST SERIES 2).		
	Sample 1	Sample 2
Cd (mg/L)	0.100	0.075
Cr ⁺⁶ (mg/L)	BDL	BDL
Cr (mg/L)	0.075	0.025
Cu (mg/L)	0.050	0.075
Fe (mg/L)	0.150	0.750
Pb (mg/L)	0.075	0.075
Ni (mg/L)	0.025	0.070
Zn (mg/L)	0.125	0.175
COD (mg/L)	48	65
Sample Identification:		
1. Sample after treatment with Norit granular carbon.		
2. Sample after treatment with Tigg powder carbon.		

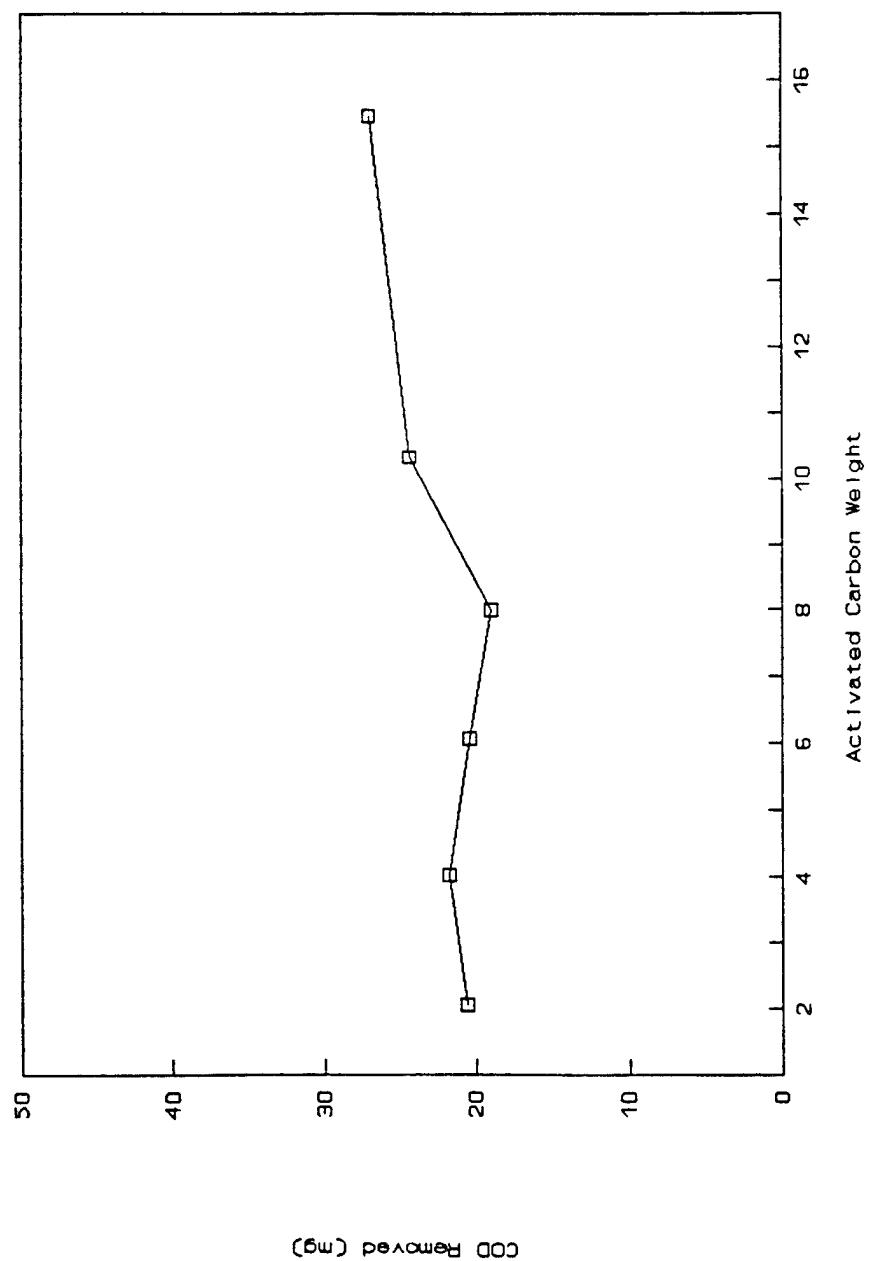


Figure 20. COD Removal Using Tigg Powder Carbon. The CAFB Wastewater Sample was Treated with the Sodium Sulfide/Ferrous Sulfate Process.

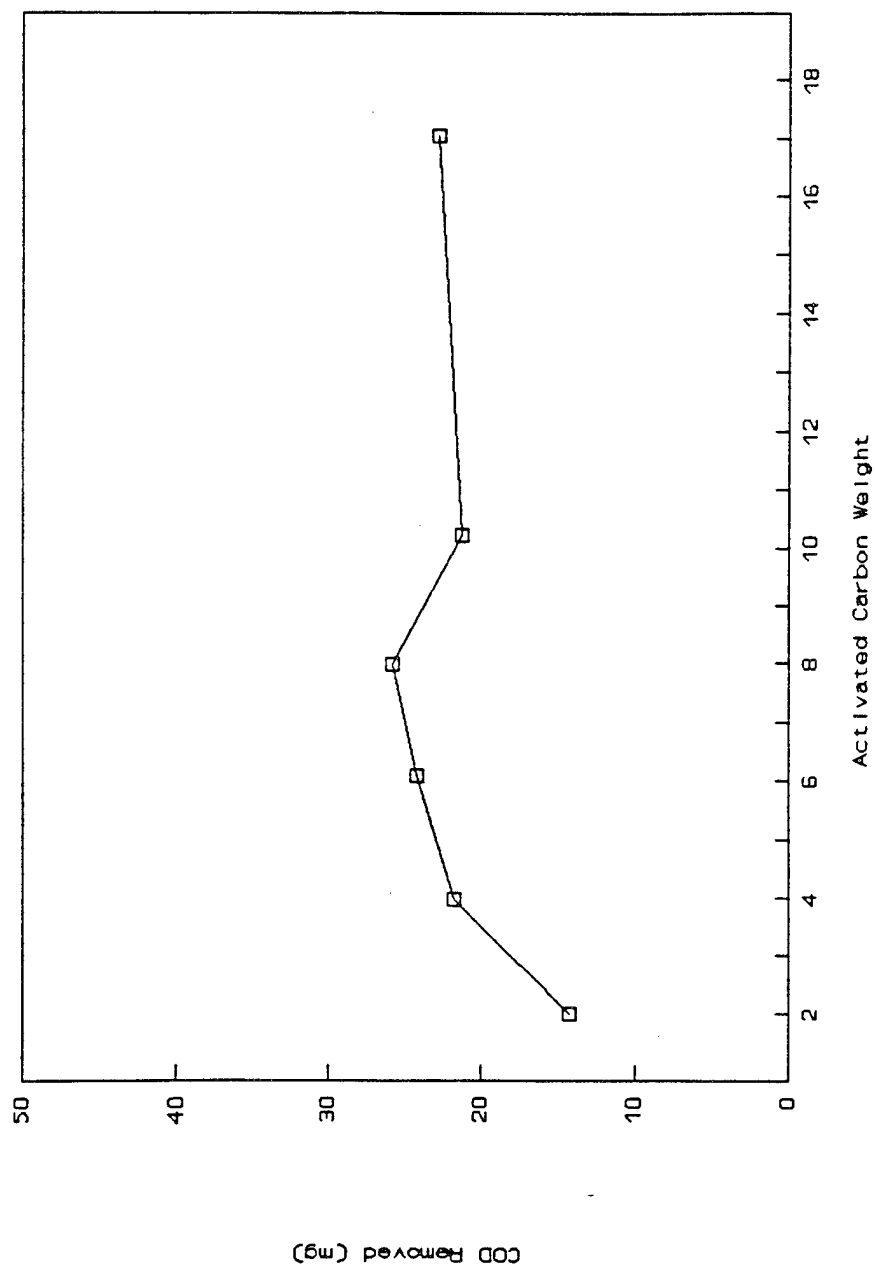


Figure 21. COD Removal with Norit Powder Carbon. The CAFB Wastewater Sample was Treated with the Fenton Process and the Sodium Sulfide/Ferrous Sulfate Process.

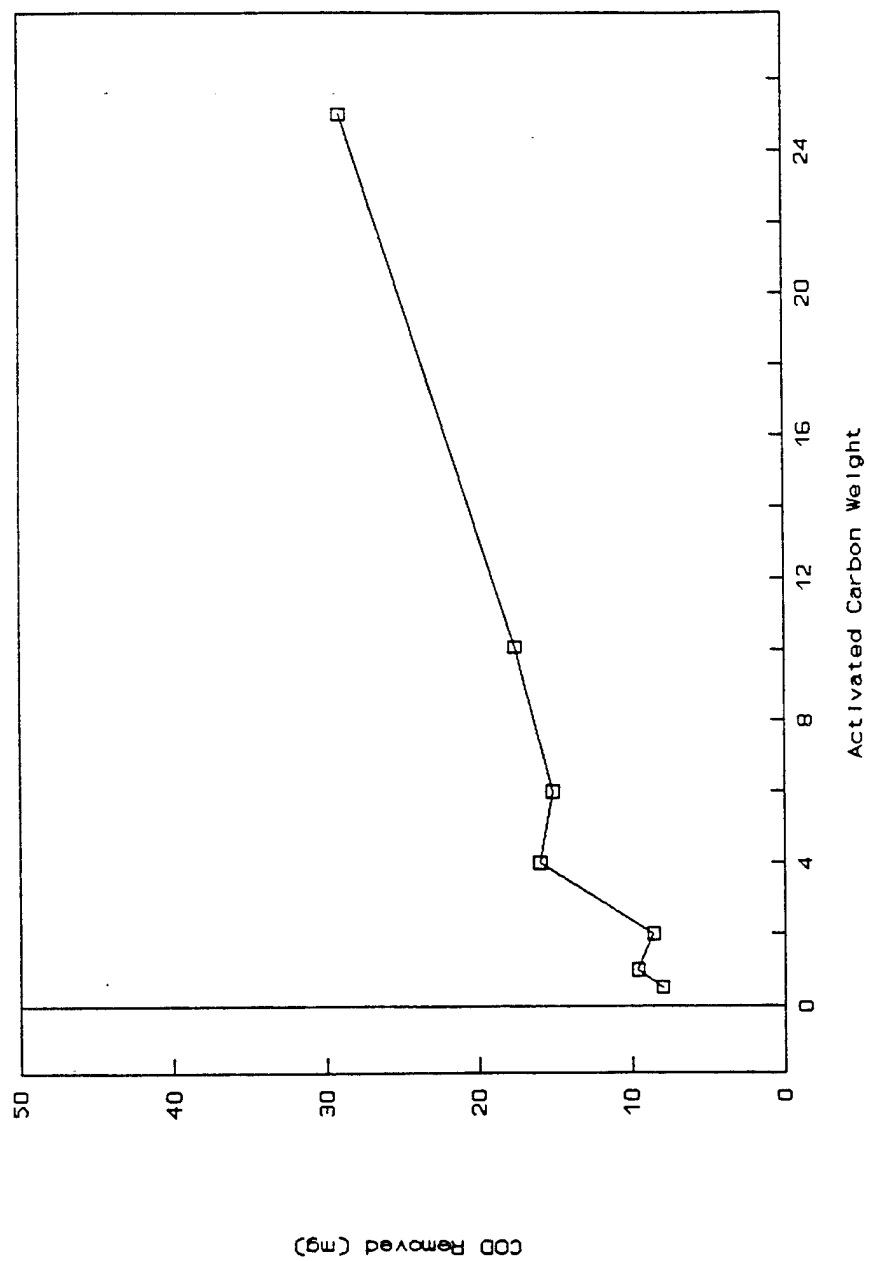


Figure 22. COD Removal with Norit Granular Carbon. The CAFB Wastewater Sample was Treated with the Fenton Process and the Sodium Sulfide/Ferrous Sulfate Process.

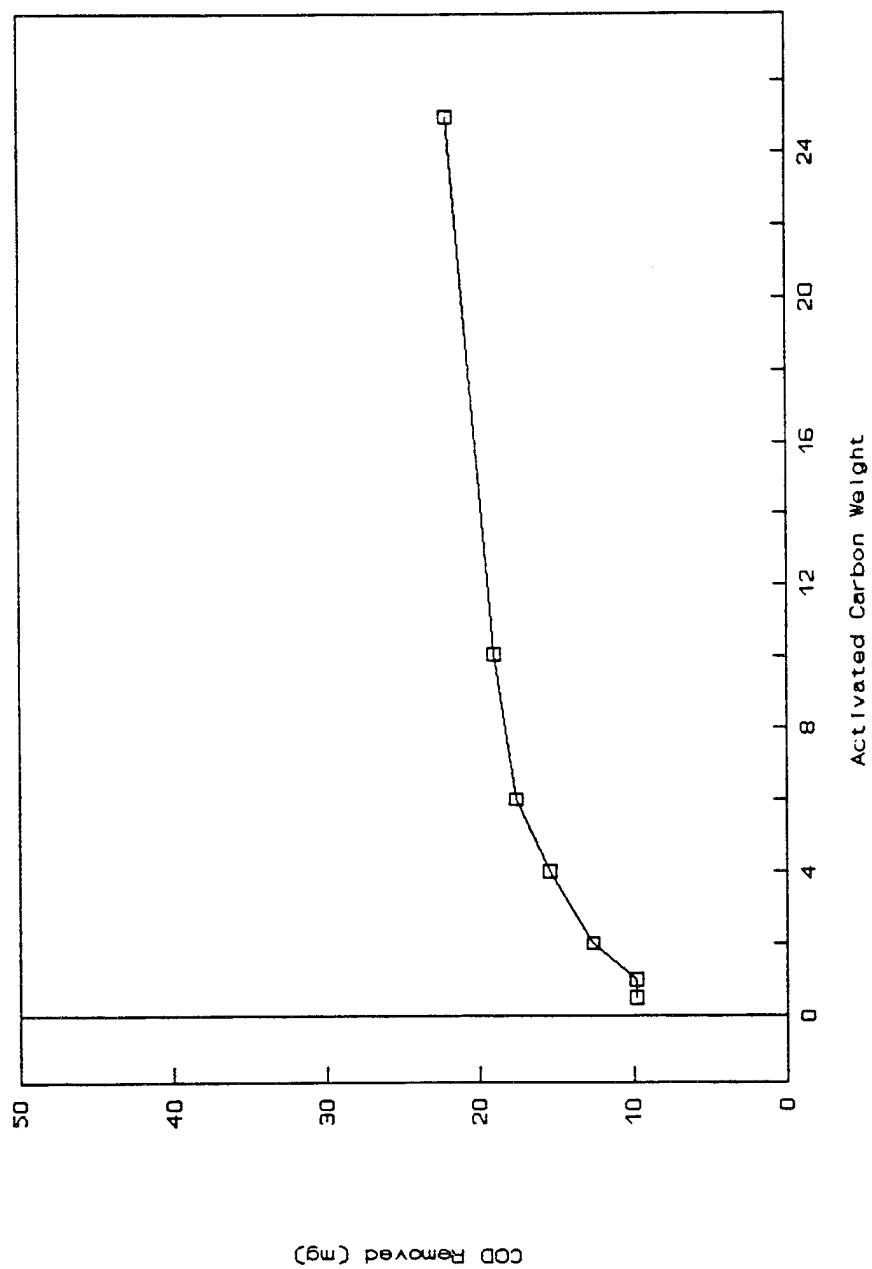


Figure 23. COD Removal with Tigg Powder Carbon. The CAFB Wastewater Sample was Treated with the Fenton Process and the Sodium Sulfide/Ferrous Sulfate Process.

SECTION IV MOBILE RESEARCH AND DEVELOPMENT TREATMENT UNIT DESIGN

A sodium sulfide/ferrous sulfate metal precipitation mobile R&D unit was designed and constructed. The primary purpose of the R&D unit is to determine the applicability of the sodium sulfide/ferrous sulfate metal treatment process to industrial waste streams generated at a number of Air Force facilities. Included in the determination of applicability are:

- (1) optimization of the sulfide ion feed concentration;
- (2) optimization of the ferrous ion concentration;
- (3) determination of the requirement for polymer and optimization of the concentration of the polymer(s);
- (4) determination of the optimum pH for operation;
- (5) determination of any chemicals in the wastestream that may cause process interference, the concentrations at which these interferences will occur, and the operational procedure to overcome the interferences; and
- (6) demonstration of the process capabilities to meet metal discharge requirements.

The discharge requirements that the sodium sulfide/ferrous sulfate process must meet will be dependent on the discharge requirements of the facility where the R&D unit is being tested. At a minimum, it is expected the treated wastewater will have to meet the EPA requirements for a metal finishing industry discharging to a domestic sewage treatment system; these are the limits shown in Table 3 (Reference 17). A second purpose of the R&D unit is to obtain the physical and chemical operating data required for design of sodium sulfide/ferrous sulfate metal treatment units for point-source treatment of metal-bearing wastewater at a number of Air Force facilities.

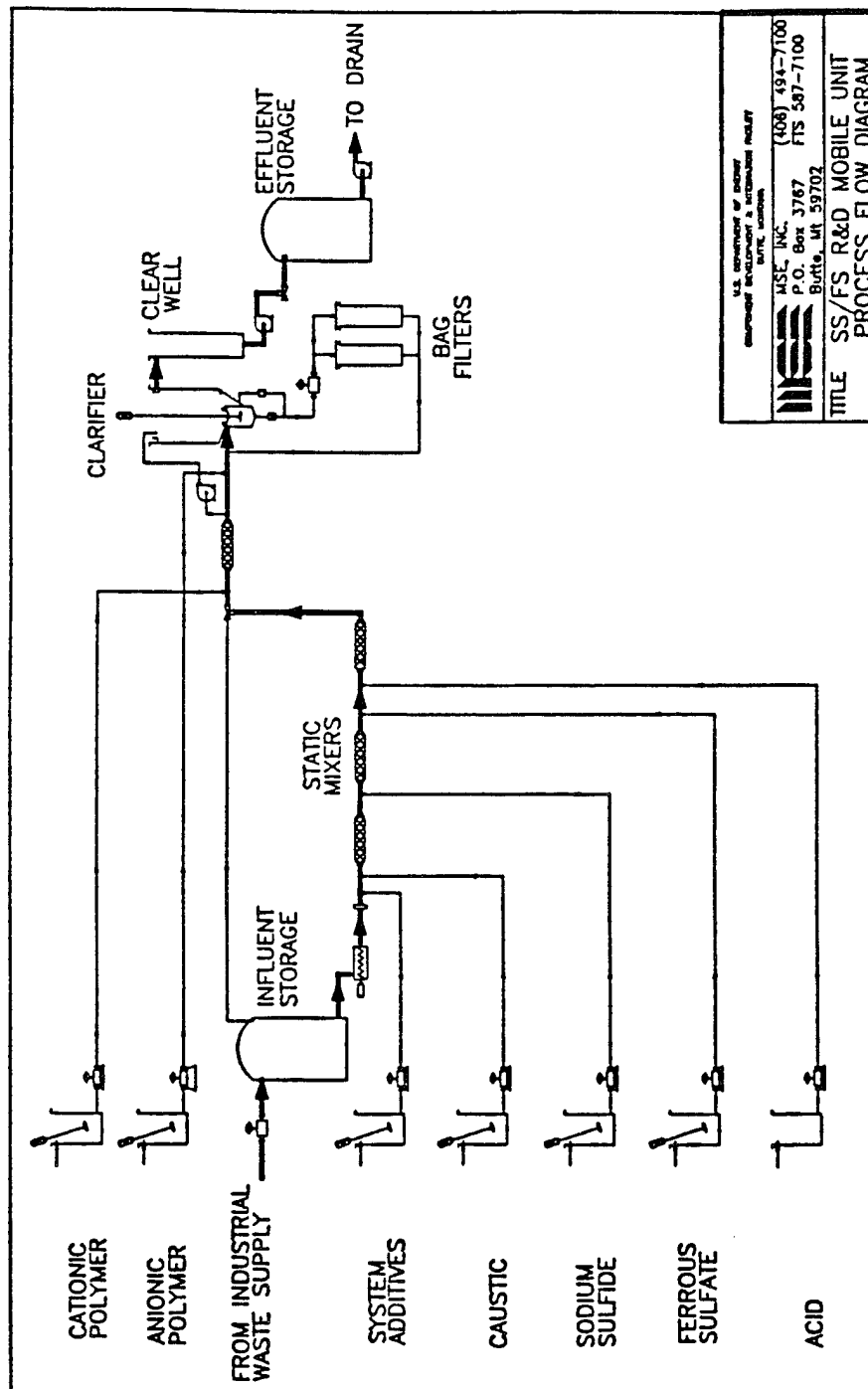
The R&D unit is only designed for heavy metals removal; it has no treatment to reduce the TTO, the COD concentration, or the oil and grease concentrations. However, there is, some reduction in these constituents inherent to the metal precipitation and sludge removal process.

Figure 24 shows a process flow diagram for the R&D unit. The unit, its components, and its operation are discussed in detail in the O&M manual (a separate document).

The unit was designed as an R&D unit, and has static mixers for mixing the chemicals required for hexavalent chromium reduction to trivalent chromium and metal precipitation. Previous testing indicates the required reactions are nearly instantaneous, and the large retention time normally required for chromium reduction is not required by the sodium sulfide/ferrous sulfate process (Reference 10). The ability to use static mixers in the chromium reduction heavy metal precipitation process can significantly reduce the size of the treatment unit and this will be important in point-source treatment where limited space is available. The use of the static mixers for this process, however, have not been evaluated at the scale of the R&D unit (2 to 8 gpm); the static mixers have been tested with the sodium sulfide/ferrous sulfate process in a bench unit at about 20 mL/min. Initial process evaluation will require verification of the operation of the static mixers.

The R&D unit also has a new clarifier unit designed for the sludge bed requirements that are typical of the sodium sulfide/ferrous sulfate process. The clarifier is designed to handle continuous flow; however, the operating parameters, have not been defined for this clarifier.

Design of the R&D unit included evaluating the use of a bag filter as an alternative to the clarifier, sludge thickener, and filter press normally required in treating industrial wastewater for heavy metal removal with a precipitation process. The use of the bag filter could significantly reduce the size and cost of the wastewater treatment unit.



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 FTS 587-7100
 TITLE SS/FS R&D MOBILE UNIT
 PROCESS FLOW DIAGRAM

Figure 24. R&D Unit Process Flow Diagram.

A. EQUIPMENT OVERVIEW

The R&D unit is designed for a flow of two to eight gpm. The equipment for the R&D unit is listed briefly below.

- (1) The influent storage tank is a 300-gallon tank that provides minimal equalization for the influent wastewater. At two gpm continuous operation, the influent storage tank provides an approximate influent retention time of 2.5 hours. The influent storage tank also allows operation in a batch mode.
- (2) The systems additives feed system allows addition of known concentrations of a chemical constituent to investigate the impact of this constituent on the process.
- (3) The caustic feed system controls the addition of caustic to the influent wastewaters and additives to ensure the solution pH is greater than 7.2. It is important the pH be 7.2 or greater prior to the addition of the sodium sulfide solution because at a lower pH, toxic hydrogen sulfide gas will be formed.
- (4) The sodium sulfide feed system is where the sodium sulfide is added to the wastewater. The sulfide ion is one of the chemical components required for reduction of hexavalent chromium to trivalent chromium. The addition of the sulfide also results in the formation of metal sulfides with the other heavy metals present. Initial concentrations are determined by laboratory testing; they are then adjusted as testing proceeds.
- (5) The ferrous sulfate feed system is where the ferrous ion is added to the wastewater. The ferrous ion with the sulfide ion results in the reduction of hexavalent chromium to trivalent chromium and also aids in floc formation. Initial concentrations are determined by laboratory testing; they are then adjusted as testing proceeds.
- (6) The sulfuric acid feed system is where sulfuric acid is added to the wastewater. Sulfuric acid controls the pH for optimum chromium reduction, metal precipitation, and final effluent clarity.
- (7) The cationic polymer feed system is where the Betz®1195 cationic polymer, a flocculation aid, is added.
- (8) The anionic polymer feed system is where the Betz®1120 anionic polymer, a flocculation aid, is added.
- (9) The clarifier is used for flocculation and settling of the precipitated metals.

- (10) The effluent storage tank is a holding tank to collect the final treated effluent before analysis to ensure discharge requirements are met. It can also be used to hold the water for further testing or for recycle or as a holding tank prior to hazardous waste disposal.
- (11) The bag filter system is for dewatering the concentrated sludge collected from the clarifier. The dewatered sludge will require disposal as a hazardous waste.

B. PROCESS AND OPERATIONAL OVERVIEW

Many Air Force operations produce heavy metal-containing wastewaters as a result of their aircraft maintenance and metal finishing procedures, and the R&D unit was designed to determine the applicability of the sodium sulfide/ ferrous sulfate metal precipitation process to these wastewaters. The treatment process chemically reduces toxic hexavalent chromium to trivalent chromium and precipitates the heavy metals. After chemical optimization of the process, the treated effluent should meet discharge requirements for heavy metals. Because the unit is an R&D unit and one objective of the R&D unit is to determine the chemical and physical operating parameters of the process, it is not to be assumed the treated effluent will meet discharge requirements during process optimization. The chemical sludges that are byproducts of the process are dewatered for disposal as a hazardous waste.

The process includes pH adjustment; the addition of sodium sulfide, ferrous sulfate, sulfuric acid, and polymers to reduce the hexavalent chromium and precipitate the heavy metals; solids removal, and sludge dewatering. All of the treatment processes in the R&D unit are sensitive to changes in the quantity and quality of the incoming wastewater.

The remaining discussion in this overview covers the process and operational logic. The discussion follows the process step-by-step from the raw influent flow through the R&D unit to the treated effluent flow into the effluent storage tank.

1. Influent Storage Tank

Wastewater is pumped from the wastewater supply to the influent storage tank. The industrial wastewater supply may be a facility industrial wastewater line, a process tank, a storage tank for industrial wastewater, or an industrial wastewater equalization tank. The influent storage tank is a 300-gallon tank that can serve for equalization of wastewater flow or can serve as a holding tank while a 300-gallon batch of the wastewater is being treated. No treatment chemicals are added to the wastewater in this tank.

2. System Additives Feed System

The wastewater is pumped from the influent storage tank to a static mixer. Chemical additives, which are added to evaluate their impact on the chromium reduction and metal precipitation and clarification process, can be added to the wastewater through a tee in front of the static mixer. The chemical additives may include EDTA, paint strippers, aqueous cleaners, cyanide, phosphates, or additional heavy metals, and their addition may require changes in the concentration of the treatment chemicals or the clarifier operation.

3. Caustic Feed System

At a second tee just in front of the first static mixer, caustic can be added to the wastewater. Caustic addition is used to raise the pH of the influent to a pH value greater than 7.2, and this addition is controlled by a pH controller. The pH is monitored by a probe downstream of the static mixer.

4. Metals Reduction and Precipitation

The wastewater with chemical additives flows to a series of three static mixers. Sodium sulfide is added upstream of the second static mixer, ferrous sulfate and sulfuric acid are added upstream of the third static mixer, and a cationic polymer can be added upstream of the final static mixer. The three static mixers provide the chemical and physical environment needed to reduce the hexavalent chromium and form a heavy metal precipitate that can settle. The polymer is added as a flocculation aid for the subsequent clarification process, and an anionic polymer is added downstream of the final static mixer as a second flocculation aid.

5. Clarification

The purpose of the clarifier is to flocculate and settle the precipitated effluent. A schematic of the clarifier is shown in Figure 25.

The clarifier can be divided into four zones as shown in Figure 25. These are the polymer mixing and solids contact zone, the sludge recycle, the sludge bed filter and flocculation zone, and the clarification zone. The clarifier has an approximate volume of 200 gallons. The lower chamber is where the anionic polymer is mixed and is the solids contact zone; the treated industrial wastewater enters the lower chamber as shown in Figure 25. A mixer mixes the lower chamber. Mixer speed controls the sludge recirculation from the upper chamber through the small ports between the lower and upper Chamber. The upper chamber is where the flocculated metals are removed from the treated industrial wastewater. The precipitated metals settle to the bottom of this chamber where they either move to the sludge hopper for removal or can be recirculated for further contact with the incoming wastewater. This increased contact with the sludge increases the floc growth and, thereby, increases the final clarity of the effluent. The clarified effluent flows over the weirs of the upper chamber of the clarifier.

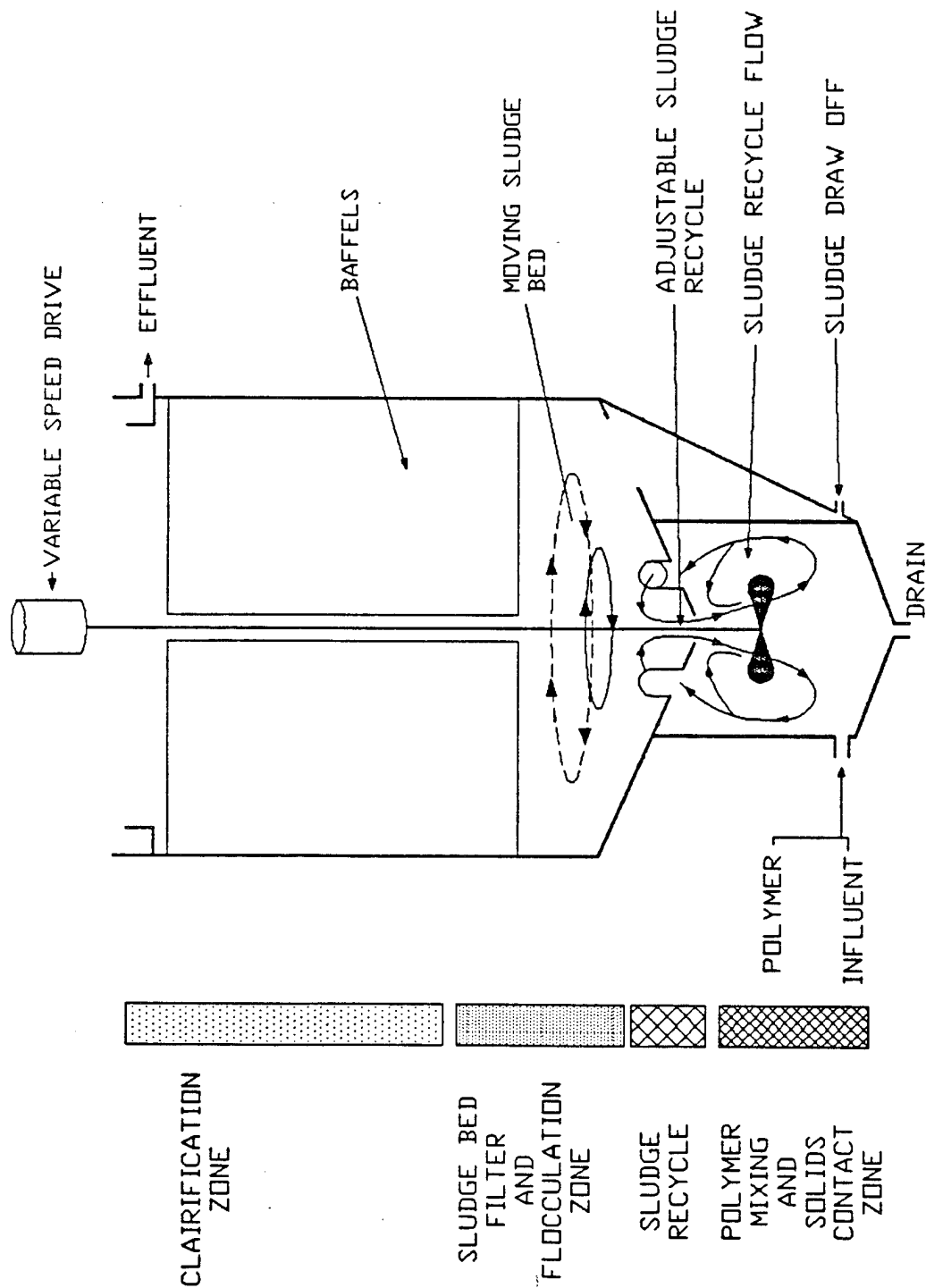


Figure 25. R&D Unit System Clarifier.

The clarifier provides a quiescent environment permitting flocculation and clarification of the flow. A high solids concentration requirement is maintained by the internal sludge recycle system. The excess sludge is pumped to the bag filters.

The clarifier design for the R&D unit is a new design, which has been submitted for patent. The clarifier was designed to meet the needs of the sodium sulfide/ferrous sulfate process and many small industrial waste streams that do not require continuous treatment. To achieve metal discharge requirements, flow through a sludge bed or sludge blanket is required with the sodium sulfide/ferrous sulfate process. In commercially available clarifiers, as much as a week may be required to generate sufficient sludge with the reduced sludge generation of the sodium sulfide/ferrous sulfate process to allow flow through a sludge blanket. This clarifier design reduces the sludge bed area and provides internal sludge recirculation to achieve added particulate contact. At the same time, the area is baffled to reduce circulation and provide a quiet zone for particulate removal. The clarifier has not yet been operated in the continuous flow mode of the R&D unit; therefore, many of the operating parameters that would normally be listed for clarifier operation have not been defined. These parameters will need to be defined with the initial operation of the R&D unit prior to evaluating the sodium sulfide/ferrous sulfate process on a number of types of industrial wastewaters. The parameters that need to be defined include the following:

- minimum and maximum sludge depth;
- sludge recirculation (as determined by the mixer speed);
- the effect of flow rate;
- start-up operating parameters versus parameters during continuous operation;
- sludge waste requirements; and
- requirements for temporary shutdown.

6. Effluent Storage Tank

The clarified flow enters a 3-gallon clear well and from there it is pumped to the effluent storage tank. At the effluent storage tank, the treated effluent can be pumped to a drain for disposal to an IWTP or a domestic sewage treatment plant or can be disposed as a hazardous wastewater. The discharge requirements of the particular facility and the discharge quality of the treated wastewater will determine the disposal. The effluent storage tank also receives bypass flow from the process (if the pH after caustic addition is not 7.2 or greater) and flow from the laboratory cabinet.

7. Bag Filters

The thickened heavy metal-containing sludge from the clarifier is pumped to the bag filters for sludge dewatering. The bags containing the dewatered sludge are disposed as a hazardous waste.

Design of the R&D unit included evaluating the use of a bag filter as an alternative to the clarifier, sludge thickener, and filter press normally required in treatment of industrial wastewater for heavy metal removal with a precipitation process. The use of the bag filter could significantly reduce the size of the wastewater treatment unit. However, the bag filter is normally used for sludge dewatering after sludge removal and thickening. The filtrate from the sludge dewatering is normally returned to the treatment process, and therefore, the filtrate does not need to meet discharge requirements. The bag filter evaluation was conducted to determine if the bag filter could be used in place of the clarifier and to see if the required effluent clarity and quality could be obtained with the bag filter.

The bag filter was evaluated at a pilot industrial wastewater treatment unit that ERAD had constructed and was operating at the Pensacola Naval Air Station in Pensacola, Florida (Reference 18 and 19). The testing was conducted in conjunction with a Naval Civil Engineering-funded program to evaluate the application of the sodium sulfide/ferrous sulfate process to the Pensacola Public Work Center industrial wastewater.

Evaluation of the bag filter was conducted by pumping the wastewater after sulfide, ferrous, cationic, and anionic polymer addition through the bag filter at 0.5 gpm; the results of this test are shown in Figures 26 and 27. The pressure increased to 25 psi within 49 minutes, and the initial turbidity was 17 FTU. With increased operation, the turbidity increased to 92 FTU, and after six hours of operation, the turbidity increased to 163 FTU. Inspection of the unit showed the bag did not remain in place during operation and allowed the wastewater to bypass the filter. The vendor was contacted, and a second seal or block was recommended. A temporary block was evaluated, and this showed the effluent turbidity could be decreased to zero. Evaluation of the wastewater revealed that with the proper seal, the bag filter was effective in removing the heavy metals to discharge requirement, generating an effluent with a turbidity of zero to five FTU. The operating pressure of the bag filter was near the maximum recommended for operation, and further studies will be required to define the filter and filter media requirement to achieve heavy metal removal while operating at a lower pump pressure. The data for the bag filter evaluation are given in Appendix F.

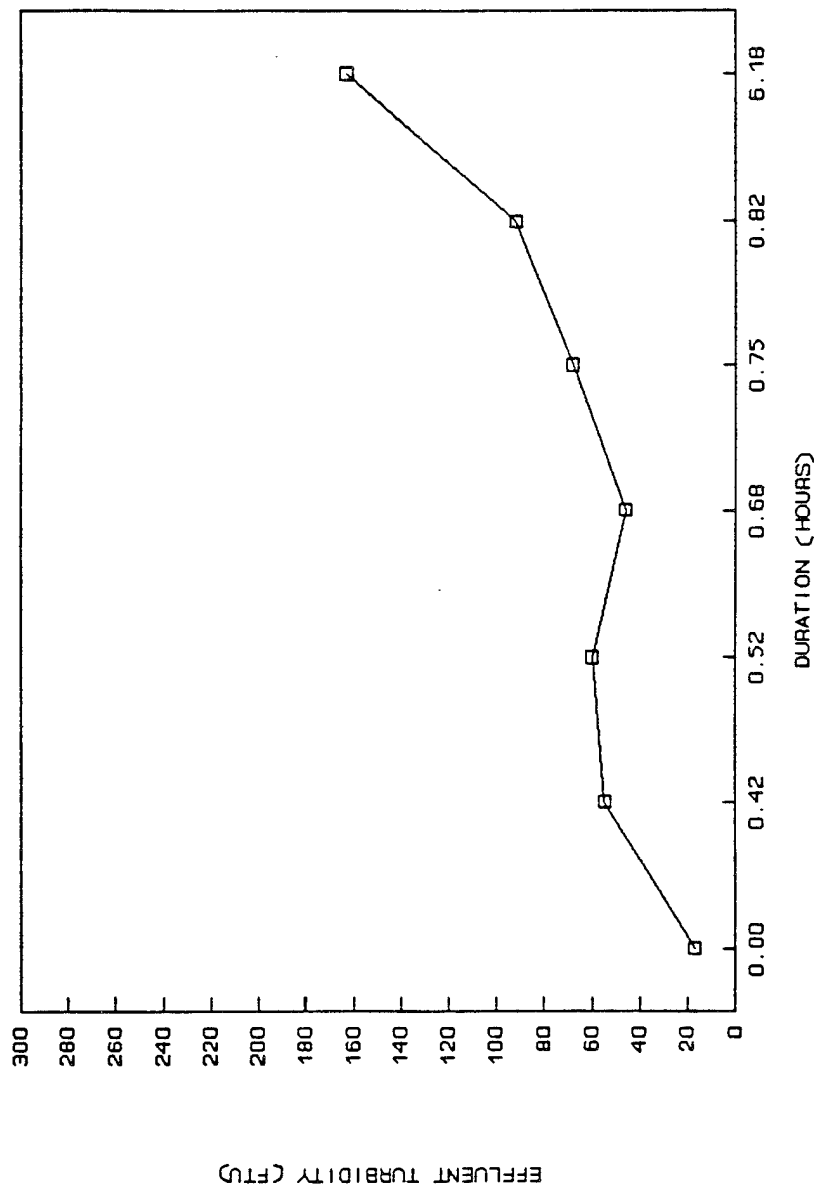


Figure 26. Effluent Turbidity from the Bag Filter as a Function of Time.

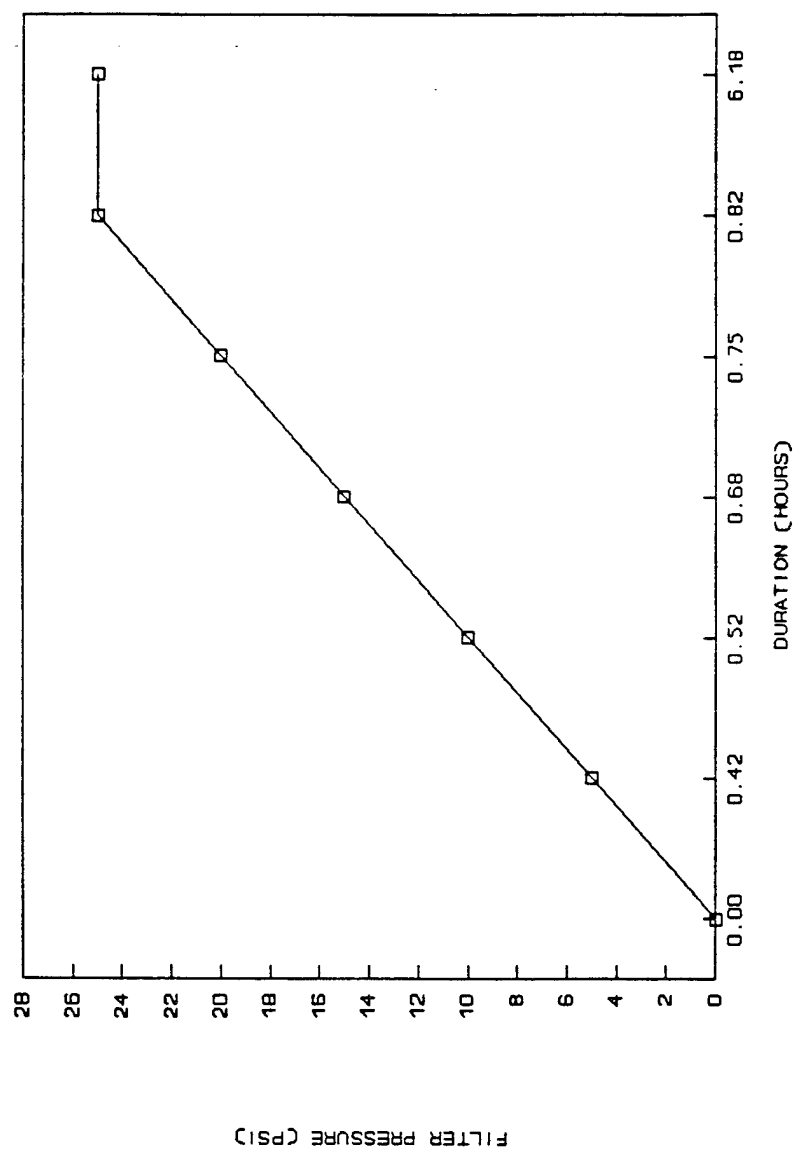


Figure 27. The Bag Filter Pressure as a Function of Time.

SECTION V CONCLUSIONS

The survey of the ALCs indicated there are a number of wastes generated at these facilities. However, it is difficult to quantify or further characterize the industrial wastewaters without actually reviewing the processes generating the wastewater and analyzing of the wastewaters.

The wastewater generated at the CAFB CCF contained heavy metals and TTOs above the discharge requirements of the domestic sewage treatment plant of the base. This wastewater would require both an organic treatment process and treatment with the sodium sulfide/ferrous sulfate process before discharge.

Heavy metal discharge requirements can be effectively achieved by treating CAFB CCF wastewater with the sodium sulfide/ferrous sulfate process. The chemical requirements for the treatment of the wastewater to metal discharge requirements with the sodium sulfide/ferrous sulfate process are listed in Table 13. These represent the chemical requirements without treatment for COD or TTO removal.

The Fenton process effectively treated the CCF wastewater to reduce the TTOs to discharge requirement. Coupled with the sodium sulfide/ferrous sulfate process, heavy metal discharge requirements were met with the final effluent having a turbidity of zero. With hexavalent chromium present after treatment with the Fenton process, additional ferrous was required to achieve chromium reduction. Without the hexavalent chromium present, sulfide and polymer addition at a pH of 7.2 to 7.5 resulted in heavy metal removal to discharge requirements. Table 14 lists the chemical requirements for treatment with the Fenton process and the sodium sulfide/ferrous sulfate process.

Oxidation of diluted samples of the CCF wastewater with the Brinecell® resulted in COD reduction to below detection; however, the size of the laboratory cell test unit prevented evaluating the process on undiluted samples due to the temperature increase with the process. It appears the Brinecell® has application to the treatment of industrial wastewater for COD reduction; the process, however, needs to be evaluated on a large scale. The existing Brinecell® units do not have the controls required to maintain the required salt concentration as the COD or TTO concentrations vary in a wastewater.

Carbon polishing was effective in removing the COD to 47 mg/L on samples of the CCF wastewater treated with the Fenton process and the sodium sulfide/ferrous sulfate process. Further COD removal could not be achieved with increased addition of the activated carbon to the wastewater. Apparently, some compounds present could not be absorbed on the carbon. Therefore, a final COD value of near zero could not be achieved.

TABLE 13. CHEMICAL REQUIREMENT FOR TREATMENT OF THE CAFB CCF WASTEWATER WITH THE SODIUM SULFIDE/FERROUS SULFATE PROCESS.

Hexavalent Chromium Present in the Sample (7 mg/l Cr ⁺⁶)	
Sodium Sulfide	2 mg/L S ⁻² :1 mg/L Cr ⁺⁶
Ferrous Sulfate	1.5 mg/L Fe ⁺² :1 mg/L Cr ⁺⁶
pH	7.2 to 7.8 pH Units
Betz®1195	20 mg/L
Betz®1120	0.5 mg/L
No Hexavalent Chromium Detected in the Sample	
Sodium Sulfide	1.0 mg/L S ⁻²
Ferrous Sulfate	1.0 mg/L Fe ⁺²
pH	7.2 to 7.8 pH Units
Betz®1195	20 mg/L
Betz®1120	0.5 mg/L

TABLE 14. CHEMICAL REQUIREMENT FOR TREATMENT OF THE CAFB WASTEWATER WITH THE FENTON PROCESS AND THE SODIUM SULFIDE/FERROUS SULFATE PROCESS.

COD Removal	
Hydrogen Peroxide	2 mg/L H_2O_2 :1 mg/L COD
Ferrous Sulfate	0.2 mg/L Fe^{+2} :1 mg/L COD
pH	3 to 5 pH Units
Heavy Metal Removal with 10 mg/L Cr^{+6} Present after COD Removal	
Sodium Sulfide	3.5 mg/L S^{-2} :1 mg/L Cr^{+6}
Ferrous Sulfate	2 mg/L Fe^{+2} :1 mg/L Cr^{+6}
pH	7.2 to 7.8 pH Units
Betz®1195 Cationic Polymer	10 mg/L
Betz®1120 Anionic Polymer	0.5 mg/L
Heavy Metal Removal with No Hexavalent Chromium Present after COD Removal	
Sodium Sulfide	2.5 mg/L S^{-2}
pH	7.2 to 7.8 pH Units
Betz®1195 Cationic Polymer	10 mg/L
Betz®1120 Anionic Polymer	0.5 mg/L

SECTION VI RECOMMENDATIONS

The Air Force has a number of production processes generating heavy metal-bearing wastewater. As indicated by the ALC survey and the data from CAFB, these wastewaters may also contain TTOs or have a high COD loading. An R&D unit was designed and constructed to determine the applicability of the sodium sulfide/ferrous sulfate metal treatment process to a number of Air Force production processes generating heavy metal-bearing wastewaters. The sodium sulfide/ferrous sulfate process can remove the heavy metals to discharge requirements for industrial wastewaters containing heavy metals as demonstrated by its successful implementation and operation at Tinker AFB and the laboratory testing conducted on the CAFB wastewater. However, the operation and design requirements have not been established for the point-source streams that may be generated at the smaller Air Force facilities. Additionally, removing the heavy metals to discharge requirements will not eliminate the need to dispose of these wastewaters as a hazardous waste when TTOs are present in the wastewaters. For these wastewaters, an organic treatment process will be required to remove the TTOs to discharge requirement and will need to be coupled to the sodium sulfide/ferrous sulfate process for heavy metal removal. After treatment with the coupled treatment process, the wastewater could be discharged to a domestic sewage treatment plant.

The following steps are recommended to define a point-source treatment process for the hazardous waste generated at the smaller Air Force facilities.

- (1) Expand the survey of the production processes generating heavy metal-bearing wastewaters to include laboratory testing to determine a) the applicability of the sodium sulfide/ferrous sulfate process to the wastewater for removal, b) the chemical operating parameters for the process, c) the identification of constituents that may interfere with the process, d) the concentrations at which the interference occurs, and e) the chemical requirements to overcome the interference.
- (2) At the same time, identify a) the other constituents that may contribute to the TTOs or may prevent discharge of the wastewater even after heavy metal removal, b) the organic loading of the wastewaters, and c) the constituents that may be contributing to the organic loading. This does not necessarily mean completely identifying the chemical species present, but identifying in general what may be present from the production process.

- (3) Conduct laboratory tests to determine the most economically and technically feasible processes for treatment to remove the TTOs to discharge requirements.
- (4) Design and construct an R&D organic treatment process(es) that may be coupled to the sodium sulfide/ferrous sulfate metal treatment R&D unit.
- (5) Select several Air Force facilities for testing and optimization of the sodium sulfide/ferrous sulfate process and the organic treatment processes; some of these facilities may only require either the metal precipitation process or the organic treatment process. Testing of these processes should also include the engineering design parameters that will be required to scaleup the treatment units or construct a unit for point-source application.

Before conducting any testing of the R&D metal-treatment unit, several operating parameters must be verified. The R&D unit has static mixers for chemical mixing and has a clarifier of new design. Testing should be conducted to verify adequate mixing and reaction time are available with the static mixers. Additionally, the operating parameters for the clarifier need to be established, and further testing needs to be conducted to determine the operation requirements and feasibility of using a bag filter as an alternative to the clarifier and filters presently required.

With the completion of the above recommendations, the data required to design and construct point-source treatment processes for the heavy metal wastewaters will be available. Implementation of the treatment processes should result in a significant cost savings to the Air Force.

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APPENDIX A

AIR FORCE SURVEY

**AIR FORCE SURVEY FOR THE SODIUM SULFIDE/FERROUS SULFATE PROCESS
WASTE TREATMENT AND DISPOSAL**

DATE: 10 Jul 92

AIR FORCE FACILITY: Weapons Components Systems Plating Shop

ADDRESS: SA/AMC Kelly AFB

B301

San Antonio, TX 78241

POINT OF CONTACT: Nancy S. Stapper

TITLE: Supervisory Chemist

NAME OF PRODUCTION PROCESS: Plating

DESCRIPTION OF PRODUCTION PROCESS: Repair of engine components through electroplating and other coatings (Please provide any available process drawings, process descriptions, or references concerning the production process.)

TYPE OF OPERATION:

Continuous X

8-hour Shift

24-hour Shift

Batch

VOLUME OF WASTE GENERATED:

Daily X

Weekly

Monthly

Annually

(Fill in the one that suits your facility)

TYPE OF WASTE:

Organic

Aqueous X

Metal-Bearing X

(Attach Most Recent Analysis of Waste, if Available)

IF AN ANALYSIS OF THE WASTE IS NOT AVAILABLE, PLEASE CHECK THE METALS WHICH MAY BE PRESENT. IF POSSIBLE, ESTIMATE A CONCENTRATION RANGE:

Cadmium	<u>0.5 lbs/mon</u>
Hexavalent Chromium	<u></u>
Chromium, Total	<u>29 lbs/mon</u>
Copper	<u></u>
Lead	<u>7.4 lbs/mon</u>
Mercury	<u></u>
Nickel	<u>15 lbs/mon</u>
Silver	<u></u>
Zinc	<u></u>
Others	<u></u>
	<u></u>
	<u></u>

LIST OTHER CONSTITUENTS WHICH MAY BE PRESENT IN THE WASTE (FOR EXAMPLE: METHYLENE CHLORIDE, PHOSPHATES, SURFACTANTS, OILS). PLEASE INCLUDE A CONCENTRATION RANGE IF KNOWN.

<u>Phosphates</u>
<u>Cyanides</u>
<u></u>
<u></u>
<u></u>

PRESENT WASTE TREATMENT: (Check all that apply)

Biological	<u></u>	
Physical	<u></u>	
Chemical	<u>X</u>	EPCF
Drummed	<u>X</u>	

AVAILABLE TREATMENT AREA: EPCF

Indoors (weather-proofed)	<u></u>
Outdoors (describe conditions for operation in cold/hot weather)	<u></u>
	<u></u>

PREFERRED TREATMENT: NA

WHAT PERCENT PAYBACK IS REQUIRED FOR ON-SITE TREATMENT: _____

TREATED WASTE WILL DISCHARGE TO:

Base Domestic Sewage Plant _____

Industrial Treatment Plant _____

Public Owned Treatment Works _____

Surface Water _____

Recycle _____

Injection _____

Attach the discharge requirements, if available, or provide an estimate of what is expected. Give a brief description of the treatment plant (i.e. lime precipitation, caustic precipitation, activated sludge, chemical treatment for organics.)

WHAT ARE THE EXPECTED CHANGES TO THE DISCHARGE REQUIREMENTS? _____

_____ PRESENT

TREATMENT AND WASTE DISPOSAL COST: _____ PRESENT

SLUDGE DISPOSAL COST: _____ EXISTING

TREATMENT EQUIPMENT AND MANUFACTURER(S): _____

_____ WHAT WOULD THE

REQUIREMENTS BE TO TEST THE PROCESS WITH A R&D TREATMENT UNIT AT YOUR FACILITY?

(Include any types of permitting requirements, monitoring requirements, discharge requirements, etc.) _____

_____ WOULD YOUR FACILITY BE INTERESTED IN BEING
SELECTED FOR TESTING?

COMMENTS: Waste from B301 plating facility is handled in following way:

1. Waste water with allowable concentration of metals and cyanide piped to EPCF pretreatment facility
2. Waste water with high concentration of metals and cyanide trucked directly to EPCF
3. Waste solutions other than water (i.e. plating baths, acids, alkalies strippers) sent to EPCF or contracted out by EM
4. Sludge drummed and disposed of through instructions from EM.

All of above are first analyzed by Chemical Processes Laboratory.

AIR FORCE SURVEY FOR THE SODIUM SULFIDE/FERROUS SULFATE PROCESS
WASTE TREATMENT AND DISPOSAL

DATE: 12 Jul 92

AIR FORCE FACILITY:

SA-ALC Kelly AFB

ADDRESS:

San Antonio, TX 78241

POINT OF CONTACT:

Nancy S. Stapper

TITLE:

Supervisory, Chemist

NAME OF PRODUCTION PROCESS:

Plating

DESCRIPTION OF PRODUCTION PROCESS: Repair of jet engine parts through electroplating includes plating (chrome, nickel, silver, cadmium), anodizing (chromic acid, sulfuric acid, hard coat), magnesium treatment (Dow 7 and 14), ion vapor deposition of aluminum, phosphate coatings, flash oxide coatings.
(Please provide any available process drawings, process descriptions, or references concerning the production process.)

TYPE OF OPERATION:

Continuous	<u> X </u>
8-hour Shift	<u> </u>
24-hour Shift	<u> </u>
Batch	<u> </u>

VOLUME OF WASTE GENERATED: Variable

Daily	<u> </u>
Weekly	<u> </u>
Monthly	<u> </u>
Annually	<u> </u>

(Fill in the one that suits your facility)

TYPE OF WASTE:

Organic	<u> </u>
Aqueous	<u> </u>
Metal-Bearing	<u> X </u>

(Attach Most Recent Analysis of Waste, if Available)

IF AN ANALYSIS OF THE WASTE IS NOT AVAILABLE, PLEASE CHECK THE METALS WHICH MAY BE PRESENT. IF POSSIBLE, ESTIMATE A CONCENTRATION RANGE:

Cadmium	<u>X</u>
Hexavalent Chromium	<u>X</u>
Chromium, Total	<u>X</u>
Copper	<u>X</u>
Lead	<u>X</u>
Mercury	<u> </u>
Nickel	<u>X</u>
Silver	<u>X</u>
Zinc	<u> </u>
Others	<u> </u>
	<u> </u>
	<u> </u>

LIST OTHER CONSTITUENTS WHICH MAY BE PRESENT IN THE WASTE (FOR EXAMPLE: METHYLENE CHLORIDE, PHOSPHATES, SURFACTANTS, OILS). PLEASE INCLUDE A CONCENTRATION RANGE IF KNOWN.

Phosphates

Cyanides

PRESENT WASTE TREATMENT: (Check all that apply)

Biological	<u> </u>
Physical	<u> </u>
Chemical	<u> </u>
Drummed	<u> X </u>

AVAILABLE TREATMENT AREA: NA

Indoors (weather-proofed)

Outdoors (describe conditions for
operation in cold/hot weather)

PREFERRED TREATMENT: NA

WHAT PERCENT PAYBACK IS REQUIRED FOR ON-SITE TREATMENT: _____

TREATED WASTE WILL DISCHARGE TO:

Base Domestic Sewage Plant _____

Industrial Treatment Plant _____

Public Owned Treatment Works _____

Surface Water _____

Recycle _____

Injection _____

Attach the discharge requirements, if available, or provide an estimate of what is expected. Give a brief description of the treatment plant (i.e. lime precipitation, caustic precipitation, activated sludge, chemical treatment for organics.)

WHAT ARE THE EXPECTED CHANGES TO THE DISCHARGE REQUIREMENTS? _____

PRESENT TREATMENT AND WASTE DISPOSAL COST: _____

PRESENT SLUDGE DISPOSAL COST: _____

EXISTING TREATMENT EQUIPMENT AND MANUFACTURER(S): _____

WHAT WOULD THE REQUIREMENTS BE TO TEST THE PROCESS WITH A R&D TREATMENT UNIT AT YOUR FACILITY? (Include any types of permitting requirements, monitoring requirements, discharge requirements, etc.)

WOULD YOUR FACILITY BE INTERESTED IN BEING SELECTED FOR TESTING?

COMMENTS: _____

AIR FORCE SURVEY FOR THE SODIUM SULFIDE/FERROUS SULFATE PROCESS
WASTE TREATMENT AND DISPOSAL

DATE: 17 Jul 92

AIR FORCE FACILITY:

Aircraft Directorate, Kelly AFB

ADDRESS:

San Antonio, TX 78241-5000

POINT OF CONTACT:

Charlie Rice

TITLE:

NAME OF PRODUCTION PROCESS:

Bicarbonate of Soda Stripping

DESCRIPTION OF PRODUCTION PROCESS: Paint Removal from components, Some Carbon Removal, Degreasing and cleaning

(Please provide any available process drawings, process descriptions, or references concerning the production process.)

TYPE OF OPERATION:

Continuous	_____
8-hour Shift	<u> X </u>
24-hour Shift	_____
Batch	_____

VOLUME OF WASTE GENERATED: Variable

Daily	_____
Weekly	_____
Monthly	_____
Annually	_____

(Fill in the one that suits your facility)

TYPE OF WASTE:

Organic	_____
Aqueous	<u> X </u>
Metal-Bearing	<u> X </u>

(Attach Most Recent Analysis of Waste, if Available)

IF AN ANALYSIS OF THE WASTE IS NOT AVAILABLE, PLEASE CHECK THE METALS WHICH MAY BE PRESENT. IF POSSIBLE, ESTIMATE A CONCENTRATION RANGE:

Cadmium	_____
Hexavalent Chromium	_____
Chromium, Total	_____
Copper	_____
Lead	_____
Mercury	_____
Nickel	_____
Silver	_____
Zinc	_____
Others	_____

LIST OTHER CONSTITUENTS WHICH MAY BE PRESENT IN THE WASTE (FOR EXAMPLE: METHYLENE CHLORIDE, PHOSPHATES, SURFACTANTS, OILS). PLEASE INCLUDE A CONCENTRATION RANGE IF KNOWN.

PRESENT WASTE TREATMENT: (Check all that apply)

Biological	_____
Physical	_____
Chemical	_____
Drummed	_____

AVAILABLE TREATMENT AREA: _____

_____ Indoors
(weather-proofed) _____

Outdoors (describe conditions for
operation in cold/hot weather) _____

PREFERRED TREATMENT: _____

WHAT

PERCENT PAYBACK IS REQUIRED FOR ON-SITE TREATMENT: _____

TREATED WASTE

WILL DISCHARGE TO:

Base Domestic Sewage Plant _____

Industrial Treatment Plant X

Public Owned Treatment Works _____

Surface Water _____

Recycle _____

Injection _____

Attach the discharge requirements, if available, or provide an estimate of what is expected. Give a brief description of the treatment plant (i.e. lime precipitation, caustic precipitation, activated sludge, chemical treatment for organics.)

WHAT ARE THE EXPECTED CHANGES TO THE DISCHARGE REQUIREMENTS? None

PRESENT

TREATMENT AND WASTE DISPOSAL COST: New Process PRESENT

SLUDGE DISPOSAL COST: _____ EXISTING

TREATMENT EQUIPMENT AND MANUFACTURER(S): _____

WHAT WOULD THE

REQUIREMENTS BE TO TEST THE PROCESS WITH A R&D TREATMENT UNIT AT YOUR FACILITY?

(Include any types of permitting requirements, monitoring requirements, discharge requirements, etc.) _____

WOULD YOUR FACILITY BE INTERESTED IN BEING

SELECTED FOR TESTING?

COMMENTS: _____

**AIR FORCE SURVEY FOR THE SODIUM SULFIDE/FERROUS SULFATE PROCESS
WASTE TREATMENT AND DISPOSAL**

DATE: 17 Jul 92

AIR FORCE FACILITY: Aircraft Directorate, Kelly AFB

ADDRESS: San Antonio, TX 78241-5000

POINT OF CONTACT: Charlie Rice

TITLE:

NAME OF PRODUCTION PROCESS: PR 3500 Aircraft Paint Stripper Waste

DESCRIPTION OF PRODUCTION PROCESS:

(Please provide any available process drawings, process descriptions, or references concerning the production process.)

TYPE OF OPERATION:

Continuous	_____
8-hour Shift	<u> X </u>
24-hour Shift	_____
Batch	_____

VOLUME OF WASTE GENERATED: Variable

Daily	_____
Weekly	_____
Monthly	_____
Annually	<u> X </u> See Below

(Fill in the one that suits your facility)

TYPE OF WASTE:

Organic	_____
Aqueous	_____
Metal-Bearing	<u> X </u>

(Attach Most Recent Analysis of Waste, if Available)

IF AN ANALYSIS OF THE WASTE IS NOT AVAILABLE, PLEASE CHECK THE METALS WHICH MAY BE PRESENT. IF POSSIBLE, ESTIMATE A CONCENTRATION RANGE:

Cadmium	_____
Hexavalent Chromium	_____
Chromium, Total	_____
Copper	_____
Lead	_____
Mercury	_____
Nickel	_____
Silver	_____
Zinc	_____
Others	_____

LIST OTHER CONSTITUENTS WHICH MAY BE PRESENT IN THE WASTE (FOR EXAMPLE: METHYLENE CHLORIDE, PHOSPHATES, SURFACTANTS, OILS). PLEASE INCLUDE A CONCENTRATION RANGE IF KNOWN.

PRESENT WASTE TREATMENT: (Check all that apply)

Biological	_____
Physical	_____
Chemical	_____
Drummed	_____

AVAILABLE TREATMENT AREA: _____

Indoors (weather-proofed) _____
Outdoors (describe conditions for
operation in cold/hot weather) _____

PREFERRED TREATMENT: _____

WHAT PERCENT PAYBACK IS REQUIRED FOR ON-SITE TREATMENT: _____

TREATED WASTE WILL DISCHARGE TO:

Base Domestic Sewage Plant _____

Industrial Treatment Plant _____

Public Owned Treatment Works _____

Surface Water _____

Recycle _____

Injection _____

Attach the discharge requirements, if available, or provide an estimate of what is expected. Give a brief description of the treatment plant (i.e. lime precipitation, caustic precipitation, activated sludge, chemical treatment for organics.)

WHAT ARE THE EXPECTED CHANGES TO THE DISCHARGE REQUIREMENTS? _____

PRESENT TREATMENT AND WASTE DISPOSAL COST: _____

PRESENT SLUDGE DISPOSAL COST: _____

EXISTING TREATMENT EQUIPMENT AND MANUFACTURER(S): _____

WHAT WOULD THE REQUIREMENTS BE TO TEST THE PROCESS WITH A R&D TREATMENT UNIT AT YOUR FACILITY? (Include any types of permitting requirements, monitoring requirements, discharge requirements, etc.) _____

WOULD YOUR FACILITY BE INTERESTED IN BEING SELECTED FOR TESTING?

COMMENTS: _____

VOLUME OF WASTES GENERATED

Equipment Wash Rinse Waters	91,878,650 #'s
Vehicle Washdown Wash Waters	59,070,113 #'s
Cyanide Bearing Waste	
from Nickel Stripping	366,520 #'s
Heavy Metal Wastewater	14,844,060 #'s
Paint Stripping Rinse Water	19,690,038 #'s

AIR FORCE SURVEY FOR THE SODIUM SULFIDE/FERROUS SULFATE PROCESS
WASTE TREATMENT AND DISPOSAL

DATE: 17 Jul 92

AIR FORCE FACILITY: Aircraft Directorate, Kelly AFB

ADDRESS: San Antonio, TX 78241-5000

POINT OF CONTACT: Charlie Rice

TITLE:

NAME OF PRODUCTION PROCESS: Cooling/Cutting Fluids From Machine Shops

DESCRIPTION OF PRODUCTION PROCESS:

(Please provide any available process drawings, process descriptions, or references concerning the production process.)

TYPE OF OPERATION:

Continuous _____
8-hour Shift _____
24-hour Shift _____
Batch _____

VOLUME OF WASTE GENERATED: Variable

Daily _____
Weekly _____
Monthly _____
Annually X See Below

(Fill in the one that suits your facility)

TYPE OF WASTE:

Organic _____
Aqueous _____
Metal-Bearing X

(Attach Most Recent Analysis of Waste, if Available)

IF AN ANALYSIS OF THE WASTE IS NOT AVAILABLE, PLEASE CHECK THE METALS WHICH MAY BE PRESENT. IF POSSIBLE, ESTIMATE A CONCENTRATION RANGE:

Cadmium	_____
Hexavalent Chromium	_____
Chromium, Total	_____
Copper	_____
Lead	_____
Mercury	_____
Nickel	_____
Silver	_____
Zinc	_____
Others	_____

LIST OTHER CONSTITUENTS WHICH MAY BE PRESENT IN THE WASTE (FOR EXAMPLE: METHYLENE CHLORIDE, PHOSPHATES, SURFACTANTS, OILS). PLEASE INCLUDE A CONCENTRATION RANGE IF KNOWN.

PRESENT WASTE TREATMENT: (Check all that apply)

Biological	_____
Physical	_____
Chemical	_____
Drummed	_____

AVAILABLE TREATMENT AREA: _____

Indoors (weather-proofed) _____
Outdoors (describe conditions for
operation in cold/hot weather) _____

PREFERRED TREATMENT: _____

WHAT PERCENT PAYBACK IS REQUIRED FOR ON-SITE TREATMENT: _____

TREATED WASTE WILL DISCHARGE TO:

Base Domestic Sewage Plant _____

Industrial Treatment Plant _____

Public Owned Treatment Works _____

Surface Water _____

Recycle _____

Injection _____

Attach the discharge requirements, if available, or provide an estimate of what is expected. Give a brief description of the treatment plant (i.e. lime precipitation, caustic precipitation, activated sludge, chemical treatment for organics.)

WHAT ARE THE EXPECTED CHANGES TO THE DISCHARGE REQUIREMENTS? _____

PRESENT TREATMENT AND WASTE DISPOSAL COST: _____

PRESENT SLUDGE DISPOSAL COST: _____

EXISTING TREATMENT EQUIPMENT AND MANUFACTURER(S): _____

WHAT WOULD THE REQUIREMENTS BE TO TEST THE PROCESS WITH A R&D TREATMENT UNIT AT YOUR FACILITY? (Include any types of permitting requirements, monitoring requirements, discharge requirements, etc.) _____

WOULD YOUR FACILITY BE INTERESTED IN BEING SELECTED FOR TESTING? _____

COMMENTS: _____

VOLUME OF WASTES GENERATED

TWC 110460 Cutting Oil	2,782 #'s
TWC 910460 Cutting Oil	208 #'s

**AIR FORCE SURVEY FOR THE SODIUM SULFIDE/FERROUS SULFATE PROCESS
WASTE TREATMENT AND DISPOSAL**

DATE: 11 Jun 92

AIR FORCE FACILITY:

SA-ALC Kelly AFB

ADDRESS:

San Antonio, TX 78241

POINT OF CONTACT:

Joe Dunkel

TITLE:

Chemical Engineer

NAME OF PRODUCTION PROCESS:

EPCF, Industrial Waste Plant

DESCRIPTION OF PRODUCTION PROCESS: Industrial Wastewater Treatment Facility. The facility has a central treatment plant consisting of biological treatment and metal precipitation by a modified Sulfex process. Also at the facility, the wastes from the plating rinse water and paint stripping are treated for cyanide, metal precipitation, and COD removal.

(Please provide any available process drawings, process descriptions, or references concerning the production process.)

TYPE OF OPERATION:

Continuous	<u> X </u>
8-hour Shift	<u> </u>
24-hour Shift	<u> </u>
Batch	<u> </u>

VOLUME OF WASTE GENERATED:

Daily	<u> 1.24 million gal/day treated </u>
Weekly	<u> </u>
Monthly	<u> </u>
Annually	<u> </u>

(Fill in the one that suits your facility)

TYPE OF WASTE:

Organic	<u> </u>
Aqueous	<u> X </u>
Metal-Bearing	<u> X </u>

(Attach Most Recent Analysis of Waste, if Available)

IF AN ANALYSIS OF THE WASTE IS NOT AVAILABLE, PLEASE CHECK THE METALS WHICH MAY BE PRESENT. IF POSSIBLE, ESTIMATE A CONCENTRATION RANGE: (Attached)

Cadmium	_____
Hexavalent Chromium	_____
Chromium, Total	_____
Copper	_____
Lead	_____
Mercury	_____
Nickel	_____
Silver	_____
Zinc	_____
Others	_____

LIST OTHER CONSTITUENTS WHICH MAY BE PRESENT IN THE WASTE (FOR EXAMPLE: METHYLENE CHLORIDE, PHOSPHATES, SURFACTANTS, OILS). PLEASE INCLUDE A CONCENTRATION RANGE IF KNOWN.

PRESENT WASTE TREATMENT: (Check all that apply)

Biological	<u> X </u>
Physical	<u> </u>
Chemical	<u> X </u>
Drummed	<u> </u>

AVAILABLE TREATMENT AREA: Existing Industrial Treatment Plant

Indoors (weather-proofed) _____
Outdoors (describe conditions for
operation in cold/hot weather) _____

PREFERRED TREATMENT: NA

WHAT PERCENT PAYBACK IS REQUIRED FOR ON-SITE TREATMENT: _____

TREATED WASTE WILL DISCHARGE TO:

Base Domestic Sewage Plant	_____
Industrial Treatment Plant	_____
Public Owned Treatment Works	_____
Surface Water	<u>X</u>
Recycle	_____
Injection	_____

Attach the discharge requirements, if available, or provide an estimate of what is expected. Give a brief description of the treatment plant (i.e. lime precipitation, caustic precipitation, activated sludge, chemical treatment for organics.)

Modified Sulfex process. Sulfur dioxide, sulfuric acid for chromium reduction. (Sulfur dioxide, sulfuric acid is only added to the wastewater from the plating rinse). Caustic addition for pH adjustment with ferrous sulfide and polymer addition for metal precipitation.

WHAT ARE THE EXPECTED CHANGES TO THE DISCHARGE REQUIREMENTS? See Attached

PRESENT TREATMENT AND WASTE DISPOSAL COST: Approximately \$100,0000/yr

PRESENT SLUDGE DISPOSAL COST: Approximately \$180,000/yr

EXISTING TREATMENT EQUIPMENT AND MANUFACTURER(S): _____

WHAT WOULD THE REQUIREMENTS BE TO TEST THE PROCESS WITH A R&D TREATMENT UNIT AT YOUR FACILITY? (Include any types of permitting requirements, monitoring requirements, discharge requirements, etc.) _____

WOULD YOUR FACILITY BE INTERESTED IN BEING SELECTED FOR TESTING?

COMMENTS: The plating rinse water and cyanide containing wastes are treated in a separate metal precipitation process prior to introduction to the Central plant. Paint stripping waste is treated a separate metal precipitation and biological treatment process. Phenols in this wastewater may be as high as 3000 mg/L. The concentrated plating wastewater is batch treated at the treatment plant.

EPCF INFLUENT WASTE ANALYSIS											
DATE	FLOW	COD	PHENOL	TOTAL CHROMIUM	NICKEL	COPPER	ZINC	LEAD	SILVER	CADMIUM	PH
	(gpd)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	
1	1,527,238	37	0.06	0.23	0.08	0.00	0.00	0.03	0.03	0.00	7.8
2	1,371,405	0	0.27	0.02	0.02	0.00	0.03	0.10	0.04	0.00	7.8
3	1,459,137	45	0.02	0.21	0.01	0.02	0.06	0.09	0.02	0.00	7.8
4	1,910,580	56	0.53	0.81	0.07	0.01	0.14	0.07	0.02	0.00	8.0
5	658,250	31	0.16	0.18	0.00	0.02	0.05	0.00	0.02	0.00	7.7
6	1,254,530	11	0.07	0.07	0.00	0.00	0.06	0.08	0.02	0.00	8.0
7	1,566,870	43	0.04	0.21	0.07	0.00	0.01	0.00	0.02	0.00	8.1
8	1,359,518	12	0.01	1.14	0.29	0.02	0.00	0.10	0.03	0.00	8.1
9	1,411,082	50	0.09	0.80	0.32	0.01	0.00	0.06	0.02	0.00	8.0
10	1,187,210	50	0.06	1.76	0.30	0.11	0.10	0.06	0.05	0.00	8.1
11	1,049,638	10	1.44	0.10	0.00	0.05	0.13	0.09	0.03	0.00	7.9
12	986,570	11	0.03	0.05	0.00	0.05	0.10	0.06	0.03	0.02	8.2
13	1,326,572	43	2.67	0.18	0.08	0.00	0.05	0.07	0.07	0.07	8.1
14	1,471,556	139	22.16	0.38	0.12	0.00	0.05	0.12	0.07	0.08	7.8
15	1,490,282	90	0.00	0.22	0.08	0.00	0.07	0.18	0.07	0.08	7.6
16	1,629,937	72	0.17	0.31	0.07	0.00	0.04	0.22	0.03	0.00	7.6
17	1,563,083	165	0.15	0.47	0.19	0.00	0.08	0.22	0.03	0.01	7.7
18	1,257,181	44	0.03	0.54	0.18	0.00	0.00	0.14	0.02	0.01	8.0
19	969,087	30	0.05	0.26	0.02	0.00	0.00	0.13	0.02	0.00	8.3

EPCF INFLUENT WASTE ANALYSIS (continued)											
DATE	FLOW	COD	PHENOL	TOTAL CHROMIUM	NICKEL	COPPER	ZINC	LEAD	SILVER	CADMIUM	pH
	(gpd)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	
20	1,394,152	33	0.27	0.10	0.03	0.00	0.00	0.04	0.00	0.00	8.2
21	1,409,474	10	0.09	0.17	0.00	0.00	0.02	0.05	0.00	0.00	7.8
22	1,527,463	65	0.01	0.05	0.11	0.25	0.00	0.07	0.00	0.00	7.5
23	1,527,463	25	0.20	0.43	0.14	0.02	0.01	0.08	0.02	0.00	7.6
24	1,446,440	63	0.02	0.29	0.12	0.01	0.08	0.06	0.01	0.00	8.0
25	1,248,929	7	0.02	0.00	0.03	0.00	0.03	0.12	0.01	0.00	8.0
26	860,773	33	0.05	0.09	0.03	0.00	0.00	0.17	0.01	0.00	8.1
27	1,277,080	76	0.05	0.15	0.06	0.05	0.00	0.13	0.02	0.01	8.3
28	1,454,173	150	0.00	0.38	0.08	0.08	0.04	0.10	0.02	0.04	9.2
29	1,420,265	53	0.01	0.22	0.06	0.10	0.02	0.11	0.02	0.02	8.1
30	1,473,150	60	0.02	0.21	0.06	0.06	0.01	0.17	0.03	0.00	7.8
TOT	40,489,088	1514	28.75	10.03	2.62	0.86	1.18	2.92	0.78	0.34	
MAX	1,910,580	165	22.16	1.76	0.32	0.25	0.14	0.22	0.07	0.08	9.2
MIN	658,250	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.5
AVE	1,349,636	50	0.96	0.33	0.09	0.03	0.04	0.10	0.03	0.01	8.0

EPCF EFFLUENT LIMITATIONS - MARCH 92					
	Mass (lb/day)		(mg/L)		
	Daily Avg	Daily Max	Daily Avg	Daily Max	Daily Max
Biochemical Oxygen Demand (5-day)	146	292	14.14		28.28
Chemical Oxygen Demand	1095	2190	106.06		212.12
Total Suspended Solids	125	250	12.11		24.21
Oil & Grease	125	188	12.11		18.21
Phenols	1.3	2.6	0.13		0.25
Ammonia (as N)	30	88	2.91		8.52
Fluoride	33	44	3.20		4.26
Phosphorus	33	44	3.20		4.26
Cyanide (total)	0.63	1.25	0.06		0.12
Cyanide *	0.25	0.5	0.02		0.05
Chromium	3.1	6.3	0.30		0.61
Nickel	7.3	14.6	0.71		1.41
Copper	3.1	6.3	0.30		0.61
Zinc	3.1	6.3	0.30		0.61
Cadmium	0.37	0.74	0.04		0.07
Lead	0.63	1.25	0.06		0.12
Silver	0.63	1.25	0.06		0.12
pH	Between 6.0 and 9.0 Standard units				
Biomonitoring	NPDES permit only				
* Cyanide amenable to chlorination					

EPCF EFFLUENT LIMITATIONS - JULY 92					
	Mass (lb/day)		(mg/L)		
	Daily Avg	Daily Max	Daily Avg	Daily Max	Daily Max
Phenols	1.3	2.6	0.126		0.252
Cyanide (total)	0.15	0.32	0.015		0.031
Cyanide *	0.25	0.41	0.024		0.040
Chromium (trivalent)	28.5	68.3	2.760		6.616
Chromium (hexavalent)	0.78	1.64	0.076		0.159
Nickel	7.3	14.6	0.707		1.414
Copper	1.05	2.24	0.102		0.217
Cadmium	0.12	0.26	0.012		0.025
Lead	0.2	0.42	0.019		0.041
Silver	0.007	0.015	0.001		0.001
* Cyanide amenable to chlorination					

**AIR FORCE SURVEY FOR THE SODIUM SULFIDE/FERROUS SULFATE PROCESS
WASTE TREATMENT AND DISPOSAL**

DATE: 7 Jul 92 - meeting

AIR FORCE FACILITY:

Tinker AFB

ADDRESS:

OC-ALC/LAPEP

Tinker AFB, OK 73145

POINT OF CONTACT:

Bill Cain

TITLE:

NAME OF PRODUCTION PROCESS:

Aircraft Stripping and Painting

DESCRIPTION OF PRODUCTION PROCESS: Methylene chloride/phenol solution is used to strip the aircrafts. Two type of strippers are used, dependent on top coat. Aircraft washed with a phosphoric acid etchant, allodyne applied according to Mil MC81709, 500 to 600 gal of Allodyne solution (2 to 3%Cr) per aircraft. (Please provide any available process drawings, process descriptions, or references concerning the production process.)

TYPE OF OPERATION:

Continuous	_____
8-hour Shift	<u> X </u>
24-hour Shift	_____
Batch	_____

VOLUME OF WASTE GENERATED:

Daily	_____
Weekly	_____
Monthly	_____
Annually	_____

(Fill in the one that suits your facility)

TYPE OF WASTE:

Organic	<u> X </u>
Aqueous	<u> X </u>
Metal-Bearing	<u> X </u>

(Attach Most Recent Analysis of Waste, if Available)

IF AN ANALYSIS OF THE WASTE IS NOT AVAILABLE, PLEASE CHECK THE METALS WHICH MAY BE PRESENT. IF POSSIBLE, ESTIMATE A CONCENTRATION RANGE:

Cadmium	_____
Hexavalent Chromium	_____ X _____
Chromium, Total	_____ X _____
Copper	_____
Lead	_____
Mercury	_____
Nickel	_____
Silver	_____
Zinc	_____
Others	_____

LIST OTHER CONSTITUENTS WHICH MAY BE PRESENT IN THE WASTE (FOR EXAMPLE: METHYLENE CHLORIDE, PHOSPHATES, SURFACTANTS, OILS). PLEASE INCLUDE A CONCENTRATION RANGE IF KNOWN.

Phosphates	_____
Methylene Chloride	_____
Phenol	_____
_____	_____
_____	_____

PRESENT WASTE TREATMENT: (Check all that apply) Limited stripping waste from 2280 and 2122 are treated at the Tinker AFB IWTP. Paint Sludge is drummed) Rags from application of spot allodyne is drummed.

Biological	_____ X _____
Physical	_____ X _____
Chemical	_____ X _____
Drummed	_____ X _____

AVAILABLE TREATMENT AREA: NA

Indoors (weather-proofed) _____

Outdoors (describe conditions for operation in cold/hot weather) _____

PREFERRED TREATMENT: _____

WHAT PERCENT PAYBACK IS REQUIRED FOR ON-SITE TREATMENT: _____

TREATED WASTE WILL DISCHARGE TO:

Base Domestic Sewage Plant _____

Industrial Treatment Plant X

Public Owned Treatment Works _____

Surface Water _____

Recycle _____

Injection _____

Attach the discharge requirements, if available, or provide an estimate of what is expected. Give a brief description of the treatment plant (i.e. lime precipitation, caustic precipitation, activated sludge, chemical treatment for organics.)

WHAT ARE THE EXPECTED CHANGES TO THE DISCHARGE REQUIREMENTS? _____

PRESENT TREATMENT AND WASTE DISPOSAL COST: _____

PRESENT SLUDGE DISPOSAL COST: _____

EXISTING TREATMENT EQUIPMENT AND MANUFACTURER(S): _____

WHAT WOULD THE REQUIREMENTS BE TO TEST THE PROCESS WITH A R&D TREATMENT UNIT AT YOUR FACILITY? (Include any types of permitting requirements, monitoring requirements, discharge requirements, etc.) _____

WOULD YOUR FACILITY BE INTERESTED IN BEING SELECTED FOR TESTING? _____

COMMENTS: The operation can handle 200 aircraft per year. The general load is 75 percent 135s and B52s. Every 8 years, an aircraft is completely refinished. Touchup is every four years. The primer coat has chromium or a leachable form of chrome. The paint sludge is disposed of as a hazardous waste (drummed). Approximately thirty 55-gallon drums/mo. A limited amount of stripper goes to the IWTP D1 and D2 tanks where it is metered into the treatment plant. Approximately 60 aircraft/yr get a full allodyne treatment. 500 to 600 gallons of allodyne solution having two to three percent chromium is applied per aircraft. This water goes to the treatment plant. Approximately 40 aircraft receive touchup. Minor allodyne applied in the dock area with cheese cloth. The contaminated cheese cloth is drummed. Approximately two drum/mo or 30 drum/yr of contaminated rags.

Some small parts are cleaned by bead blasting. The soft skins do not permit bead blasting on the aircraft. They are looking at LARPS, a high-pressure water process. In this application, the water could be filtered and recycled with monitoring of the metals. Have investigated nonchromated allodyning. However coupon tests did not give the adhesion or corrosion protection required. Have investigated a benzyl alcohol stripper. The stripper was effective on the primer. Required additional time on the topcoat. However, the time requirement would not seriously impact production. If applied would eliminate or reduce the requirement for the methylene chloride phenol stripper.

AIR FORCE SURVEY FOR THE SODIUM SULFIDE/FERROUS SULFATE PROCESS
WASTE TREATMENT AND DISPOSAL

DATE: 8 Jul 92 - meeting

AIR FORCE FACILITY:

Tinker AFB

ADDRESS:

OC-ALC/MAENP

Tinker AFB, OK 73145

POINT OF CONTACT:

Mike Patry

TITLE:

NAME OF PRODUCTION PROCESS:

Chemical Cleaning and plating

DESCRIPTION OF PRODUCTION PROCESS: _____

(Please provide any available process drawings, process descriptions, or references concerning the production process.)

TYPE OF OPERATION:

Continuous _____

8-hour Shift

X (approximately 12 to 16 hours, 6 to 7
days per week

24-hour Shift _____

Batch _____

VOLUME OF WASTE GENERATED:

Daily

60,000 gal/day

Weekly _____

Monthly _____

Annually _____

(Fill in the one that suits your facility)

TYPE OF WASTE:

Organic _____

Aqueous

X

Metal-Bearing

X

(Attach Most Recent Analysis of Waste, if Available)

IF AN ANALYSIS OF THE WASTE IS NOT AVAILABLE, PLEASE CHECK THE METALS WHICH MAY BE PRESENT. IF POSSIBLE, ESTIMATE A CONCENTRATION RANGE:

Cadmium	_____
Hexavalent Chromium	10 to 20 mg/L
Chromium, Total	_____
Copper	_____
Lead	_____
Mercury	_____
Nickel	10 to 20 mg/L
Silver	_____
Zinc	X
Others	_____

LIST OTHER CONSTITUENTS WHICH MAY BE PRESENT IN THE WASTE (FOR EXAMPLE: METHYLENE CHLORIDE, PHOSPHATES, SURFACTANTS, OILS). PLEASE INCLUDE A CONCENTRATION RANGE IF KNOWN.

Chelating Agents _____

PRESENT WASTE TREATMENT: (Check all that apply)

Biological	_____
Physical	_____
Chemical	X
Drummed	_____

AVAILABLE TREATMENT AREA: Existing treatment plant in place

Indoors (weather-proofed)	X
Outdoors (describe conditions for operation in cold/hot weather)	_____

PREFERRED TREATMENT: Chemical Precipitation

WHAT PERCENT PAYBACK IS REQUIRED FOR ON-SITE TREATMENT: NA

TREATED WASTE WILL DISCHARGE TO:

Base Domestic Sewage Plant

Industrial Treatment Plant X

Public Owned Treatment Works

Surface Water

Recycle

Injection

Attach the discharge requirements, if available, or provide an estimate of what is expected. Give a brief description of the treatment plant (i.e. lime precipitation, caustic precipitation, activated sludge, chemical treatment for organics.)

WHAT ARE THE EXPECTED CHANGES TO THE DISCHARGE REQUIREMENTS? Presently meeting EPA metal finishing requirements

PRESENT TREATMENT AND WASTE DISPOSAL COST:

PRESENT SLUDGE DISPOSAL COST: 1 to 2 drum of sludge/week

EXISTING TREATMENT EQUIPMENT AND MANUFACTURER(S):

WHAT WOULD THE REQUIREMENTS BE TO TEST THE PROCESS WITH A R&D TREATMENT UNIT AT YOUR FACILITY? (Include any types of permitting requirements, monitoring requirements, discharge requirements, etc.)

WOULD YOUR FACILITY BE INTERESTED IN BEING SELECTED FOR TESTING?

COMMENTS: Presently as much of the metals are recovered as can be. Chromate recovery is presently in place to concentrate the chromate and return to process. Nickel is recovered by ion exchange. Ion exchange room is being refurbished. Completion of this refurbishment will significantly reduce the nickel. Cadmium has been eliminated from the processing. Nickel zinc coating. Recovered nickel may be applicable to this coating process. Water is recycled in the processing to minimize the wastewater generation and the requirement for additional water.

**AIR FORCE SURVEY FOR THE SODIUM SULFIDE/FERROUS SULFATE PROCESS
WASTE TREATMENT AND DISPOSAL**

DATE: 16 Jun 92

AIR FORCE FACILITY:

Wright-Patterson AFB OH

ADDRESS:

2750 ABW/EME

WPAFB OH 45433-5000

POINT OF CONTACT:

Shari Kilbourne

TITLE:

Environmental Specialist

NAME OF PRODUCTION PROCESS:

Printed Circuit Board Shop

DESCRIPTION OF PRODUCTION PROCESS: The work in this shop involves the building of printed circuit boards using various solutions to etch away metal portions of the circuit boards

(Please provide any available process drawings, process descriptions, or references concerning the production process.)

TYPE OF OPERATION:

Continuous _____

8-hour Shift X

24-hour Shift _____

Batch _____

VOLUME OF WASTE GENERATED: Unknown

Daily _____

Weekly _____

Monthly _____

Annually _____

(Fill in the one that suits your facility)

TYPE OF WASTE:

Organic _____

Aqueous X

Metal-Bearing _____

(Attach Most Recent Analysis of Waste, if Available)

IF AN ANALYSIS OF THE WASTE IS NOT AVAILABLE, PLEASE CHECK THE METALS WHICH MAY BE PRESENT. IF POSSIBLE, ESTIMATE A CONCENTRATION RANGE: Analytical Data Attached.

Cadmium	_____
Hexavalent Chromium	_____
Chromium, Total	_____
Copper	_____
Lead	_____
Mercury	_____
Nickel	_____
Silver	_____
Zinc	_____
Others	_____

LIST OTHER CONSTITUENTS WHICH MAY BE PRESENT IN THE WASTE (FOR EXAMPLE: METHYLENE CHLORIDE, PHOSPHATES, SURFACTANTS, OILS). PLEASE INCLUDE A CONCENTRATION RANGE IF KNOWN.

1.1.1-Trichloroethane _____

PRESENT WASTE TREATMENT: (Check all that apply) None

Biological	_____
Physical	_____
Chemical	_____
Drummed	_____

AVAILABLE TREATMENT AREA: City of Data Wastewater Treatment Plant currently treats the wastewater.

Indoors (weather-proofed) Limited space for on site systems
Outdoors (describe conditions for
operation in cold/hot weather) _____

PREFERRED TREATMENT: None

WHAT PERCENT PAYBACK IS REQUIRED FOR ON-SITE TREATMENT: _____

TREATED WASTE WILL DISCHARGE TO:

Base Domestic Sewage Plant	_____
Industrial Treatment Plant	_____
Public Owned Treatment Works	<u>X</u>
Surface Water	_____
Recycle	_____
Injection	_____

Attach the discharge requirements, if available, or provide an estimate of what is expected. Give a brief description of the treatment plant (i.e. lime precipitation, caustic precipitation, activated sludge, chemical treatment for organics.)

WHAT ARE THE EXPECTED CHANGES TO THE DISCHARGE REQUIREMENTS? Metal limits will be lowered. Mercury will be added to the requirements. See Attachment 3 for current discharge requirements.

PRESENT TREATMENT AND WASTE DISPOSAL COST: \$92,102.30/month is the total cost for discharging to the City of Dayton (0.98 per 1,000 gallons)

PRESENT SLUDGE DISPOSAL COST: \$1.75 to \$3.25 per pound depending on which contract line item (CLIN) is used.

EXISTING TREATMENT EQUIPMENT AND MANUFACTURER(S): None

WHAT WOULD THE REQUIREMENTS BE TO TEST THE PROCESS WITH A R&D TREATMENT UNIT AT YOUR FACILITY? (Include any types of permitting requirements, monitoring requirements, discharge requirements, etc.) This facility has been issued administrative orders with monitoring requirements by the city of Dayton. Attached is the current discharge requirements. Need PTI for long term test, no additional monitoring requirements.

WOULD YOUR FACILITY BE INTERESTED IN BEING SELECTED FOR TESTING?

COMMENTS: We would welcome any additional information on types/options of pretreatment systems available

AIR FORCE SURVEY FOR THE SODIUM SULFIDE/FERROUS SULFATE PROCESS
WASTE TREATMENT AND DISPOSAL

DATE: 16 Jun 92

AIR FORCE FACILITY:

Wright-Patterson AFB

ADDRESS:

2750 ABW/EME

WPAFB OH 45433-5000

POINT OF CONTACT:

Shari Kilbourne

TITLE:

Environmental Specialist

NAME OF PRODUCTION PROCESS:

Plating Shop - Fac 20005

DESCRIPTION OF PRODUCTION PROCESS: The work in this shop involves plating and/or treating metal parts by dipping the parts into tanks of various solutions. The majority of the processed parts are aluminum, but some copper, brass, ferrous metals, stainless steel, and nickel alloys are also treated. (Please provide any available process drawings, process descriptions, or references concerning the production process.)

TYPE OF OPERATION:

Continuous	_____
8-hour Shift	<u> X </u>
24-hour Shift	_____
Batch	_____

VOLUME OF WASTE GENERATED:

Daily	<u>15,000 gallons/day of wastewater</u>
Weekly	_____
Monthly	_____
Annually	_____

(Fill in the one that suits your facility)

TYPE OF WASTE:

Organic	_____
Aqueous	<u> X </u>
Metal-Bearing	_____

(Attach Most Recent Analysis of Waste, if Available)

IF AN ANALYSIS OF THE WASTE IS NOT AVAILABLE, PLEASE CHECK THE METALS WHICH MAY BE PRESENT. IF POSSIBLE, ESTIMATE A CONCENTRATION RANGE: Analytical Data Attached.

Cadmium	_____
Hexavalent Chromium	_____
Chromium, Total	_____
Copper	_____
Lead	_____
Mercury	_____
Nickel	_____
Silver	_____
Zinc	_____
Others	_____

LIST OTHER CONSTITUENTS WHICH MAY BE PRESENT IN THE WASTE (FOR EXAMPLE: METHYLENE CHLORIDE, PHOSPHATES, SURFACTANTS, OILS). PLEASE INCLUDE A CONCENTRATION RANGE IF KNOWN.

PRESENT WASTE TREATMENT: (Check all that apply)

Biological	_____
Physical	_____
Chemical	_____
Drummed	_____

AVAILABLE TREATMENT AREA: City of Dayton Wastewater Treatment Plant currently treats the wastewater.

Indoors (weather-proofed) Limited space for on site systems.
Outdoors (describe conditions for
operation in cold/hot weather) _____

PREFERRED TREATMENT: None

WHAT PERCENT PAYBACK IS REQUIRED FOR ON-SITE TREATMENT: Not Applicable

TREATED WASTE WILL DISCHARGE TO:

Base Domestic Sewage Plant	_____
Industrial Treatment Plant	_____
Public Owned Treatment Works	<u> X </u>
Surface Water	_____
Recycle	_____
Injection	_____

Attach the discharge requirements, if available, or provide an estimate of what is expected. Give a brief description of the treatment plant (i.e. lime precipitation, caustic precipitation, activated sludge, chemical treatment for organics.)

WHAT ARE THE EXPECTED CHANGES TO THE DISCHARGE REQUIREMENTS? Metal limits will be lowered. Mercury will be added to the requirements. See Attachment 3 for current discharge requirements.

PRESENT TREATMENT AND WASTE DISPOSAL COST: \$92,102.30/month is the total cost for discharging to the City of Dayton (\$0.98 per 1,000 gallons).

PRESENT SLUDGE DISPOSAL COST: \$1.75 to \$3.25 per lb. depending on which Contract Line Item (CLIN) is used.

EXISTING TREATMENT EQUIPMENT AND MANUFACTURER(S): None, Currently research is being done to determine what type of pretreatment system(s) could be used at the Printed Circuit Board Shop.

WHAT WOULD THE REQUIREMENTS BE TO TEST THE PROCESS WITH A R&D TREATMENT UNIT AT YOUR FACILITY? (Include any types of permitting requirements, monitoring requirements, discharge requirements, etc.) This facility has been issued administrative orders with monitoring requirements by the city of Dayton. Attached is the current discharge requirements. Need PTI for long term test, no additional monitoring requirements.

WOULD YOUR FACILITY BE INTERESTED IN BEING SELECTED FOR TESTING? Research is being done right now on what type of pretreatment system could be used at the Printed Circuit Board Shop.

COMMENTS: We would welcome any additional information on types/options of pretreatment systems available.

CURRENT DISCHARGE REQUIREMENTS

Sampling Location:

1. Plating Shop drain pit (inside building)
2. Printed Circuit Board Shop - outside sampling port.

Discharge from the permittee shall meet the following effluent standards. Analysis of samples from the above sampling locations taken in accordance with ORDERS-Section 5, - sampled and analyzed with EPA approved methods - shall meet the following effluent standards:

<u>Parameter</u>	<u>1-day Maximum (mg/L)</u>	<u>30-day Average (mg/L)</u>
Cadmium	0.69	0.26
Chromium	2.77	1.71
Copper	3.38	2.07
Lead	0.65	0.43
Nickel	3.98	2.38
Zinc	2.61	1.48
Silver	0.43	0.24
Cyanide (Total)	1.20	0.65
TTO	2.13	

ANALYTICAL REPORT

Wright Patterson AFB
2750 ABW/EM
Bldg. 89, Area C
WPAFB, OH 45433
Sample Description: EM920686
Date Taken: 05/19/1992

06/08/1992

PESTICIDES/PCBs - 608

Aldrin	△0.2	μg/L
alpha-BHC	△0.2	μg/L
beta-BHC	△0.2	μg/L
gamma-BHC (Lindane)	△0.2	μg/L
delta-BHC	△0.2	μg/L
Chlordane	△0.2	μg/L
4,4'-DDD	△0.2	μg/L
4,4'-DDE	△0.2	μg/L
4,4'-DDT	△0.2	μg/L
Dieldrin	△0.2	μg/L
Endosulfan I	△0.2	μg/L
Endosulfan II	△0.2	μg/L
Endosulfan Sulfate	△0.2	μg/L
Endrin	△0.2	μg/L
Endrin Aldehyde	△0.2	μg/L
Heptachlor	△0.2	μg/L
Toxaphene	△0.2	μg/L
PCB-1016	△0.2	μg/L
PCB-1221	△0.2	μg/L
PCB-1232	△0.2	μg/L
PCB-1242	△0.2	μg/L
PCB-1248	△0.2	μg/L
PCB-1254	△0.2	μg/L
PCB-1260	△0.2	μg/L
PCB Standard: Aroclor 1242	98	%
PCB Standard: Aroclor 1260	99	%
Pesticide Standard	92/106	%

ANALYTICAL REPORT

Wright Patterson AFB

06/08/1992

2750 ABW/EM

Bldg. 89, Area C

WPAFB, OH 45433

Sample Description: EM920686

Date Taken: 05/19/1992

ACID COMPOUNDS - 625

4-Chloro-3-methylphenol	<4.	µg/L
2-Chlorophenol	<4.	µg/L
2,4-Dichlorophenol	<4.	µg/L
2,4-Dimethylphenol	<4.	µg/L
2,4-Dinitrophenol	<4.	µg/L
2-Methyl-4,6-dinitrophenol	<4.	µg/L
2-Nitrophenol	<4.	µg/L
4-Nitrophenol	<4.	µg/L
Pentachlorophenol	<4.	µg/L
Phenol	<4.	µg/L
2,4,6-Trichlorophenol	<4.	µg/L
Surrogate: d6-Phenol	24	%
Surrogate: 2-Fluorophenol	58	%
Surrogate: Tribromophenol	64	%

ANALYTICAL REPORT

Wright Patterson AFB
2750 ABW/EM
Bldg. 89, Area C
WPAFB, OH 45433
Sample Description: EM920686
Date Taken: 05/19/1992

06/08/1992

BASE NEUTRAL COMPOUNDS - 625

2,4-Dinitrotoluene	<4.	µg/L
2,6-Dinitrotoluene	<4.	µg/L
Di-n-octylphthalate	<4.	µg/L
Fluoranthene	<4.	µg/L
Fluorene	<4.	µg/L
Hexachlorobenzene	<4.	µg/L
Hexachloro-1,3-butadiene	<4.	µg/L
Hexachlorocyclopentadiene	<4.	µg/L
Hexachloroethane	<4.	µg/L
Indeno (1,2,3-cd)pyrene	<4.	µg/L
Isophorone	<4.	µg/L
Naphthalene	<4.	µg/L
Nitrobenzene	<4.	µg/L
N-Nitrosodimethylamine	<4.	µg/L
N-Nitrosodiphenylamine	<4.	µg/L
N-Nitroso di-n-propylamine	<4.	µg/L
Phenanthrene	<4.	µg/L
Pyrene	<4.	µg/L
1,2,4-Trichlorobenzene	<4.	µg/L
Surrogate: d5-Nitrobenzene	78	%
Surrogate: 2-Fluorobiphenyl	74	%
Surrogate: d14-Terphenyl	70	%

ANALYTICAL REPORT

Wright Patterson AFB
2750 ABW/EM
Bldg. 89, Area C
WPAFB, OH 45433
Sample Description: EM920686
Date Taken: 05/19/1992

06/08/1992

BASE NEUTRAL COMPOUNDS - 625

Acenaphthene	<4.	µg/L
Acenaphthylene	<4.	µg/L
Anthracene	<4.	µg/L
Benzidine	<4.	µg/L
Benzo (a) anthracene	<4.	µg/L
Benzo (b) fluoranthene	<4.	µg/L
Benzo (k) fluoranthene	<4.	µg/L
Benzo (a) pyrene	<4.	µg/L
Benzo (ghi) perylene	<4.	µg/L
Benzyl butyl phthalate	<4.	µg/L
bis (2-Chloroethyl) ether	<15.	µg/L
bis (2-Chloroethoxy) methane	<15.	µg/L
bis (2-Ethylhexyl) phthalate	<4.	µg/L
bis (2-Chloroisopropyl) ether	<15.	µg/L
4-Bromophenyl phenyl ether	<15.	µg/L
2-Chloronaphthalene	<4.	µg/L
4-Chlorophenylphenyl ether	<15.	µg/L
Chrysene	<4.	µg/L
Dibenzo (a,h) anthracene	<4.	µg/L
Di-n-butylphthalate	<4.	µg/L
1,3-Dichlorobenzene	<4.	µg/L
1,2-Dichlorobenzene	<4.	µg/L
1,4-Dichlorobenzene	<4.	µg/L
3,3-Dichlorobenzidine	<15.	µg/L
Diethyl phthalate	<4.	µg/L
1,2-Diphenylhydrazine	<4.	µg/L
Dimethyl phthalate	<4.	µg/L

ANALYTICAL REPORT

Wright Patterson AFB
2750 ABW/EM
Bldg. 89, Area C
WPAFB, OH 45433
Sample Description: EM920686
Date Taken: 05/19/1992

06/08/1992

VOLATILE COMPOUNDS - 624

Acrolein	<2000.	µg/L
Acrylonitrile	<2000.	µg/L
Benzene	<100.	µg/L
Bromodichloromethane	<100.	µg/L
Bromoform	<100.	µg/L
Bromomethane	<100.	µg/L
Carbon tetrachloride	<100.	µg/L
Chlorobenzene	<100.	µg/L
Chloroethane	<100.	µg/L
2-Chloroethyl vinyl ether	<1000.	µg/L
Chloroform	<100.	µg/L
Chloromethane	<100.	µg/L
Dibromochloromethane	<100.	µg/L
1,1-Dichloroethane	<100.	µg/L
1,2-Dichloroethane	<100.	µg/L
1,1-Dichloroethene	<100.	µg/L
trans-1,2-Dichloroethene	<100.	µg/L
cis-1,2-Dichloroethane	<100.	µg/L
1,2-Dichloropropane	<100.	µg/L
cis-1,3-Dichloropropene	<100.	µg/L
trans-1,3-Dichloropropene	<100.	µg/L
Ethylbenzene	<100.	µg/L
Methylene chloride	<100.	µg/L
1,1,2,2-Tetrachloroethane	<100.	µg/L
Tetrachloroethene	<100.	µg/L
Toluene	<100.	µg/L

ANALYTICAL REPORT

Wright Patterson AFB
2750 ABW/EM
Bldg. 89, Area C
WPAFB, OH 45433
Sample Description: EM920686
Date Taken: 05/19/1992

06/08/1992

VOLATILE COMPOUNDS - 624

1,1,1-Trichloroethane	20000.	µg/L
1,1,2-Trichloroethane	<100.	µg/L
Trichloroethene	<100.	µg/L
Trichlorofluoromethane	<100.	µg/L
Vinyl chloride	<100.	µg/L
Surrogate: d4-1,2-DCE	100 See Text	%
Surrogate: d8-Toluene	99	%
Surrogate: BFB	102	%

ANALYTICAL REPORT

Wright Patterson AFB

06/08/1992

2750 ABW/EM

Bldg. 89, Area C

WPAFB, OH 45433

Sample Description: EM920686 - FAC L0005, Plating Shop

Date Taken: 05/19/1992 Date Received: 05/19/1992

Cyanide, Total	<0.005	mg/L
Cadmium, GFAA	0.177	mg/L
Chromium, Total GFAA	0.103	mg/L
Copper	0.141	mg/L
Lead, GFAA	0.0987	mg/L
Nickel, GFAA	0.046	mg/L
Silver, GFAA	<0.0010	mg/L
Zinc	0.051	mg/L

ANALYTICAL REPORT

Wright Patterson AFB
2750 ABW/EM
Bldg. 89, Area C
WPAFB, OH 45433
Date Received: 01/02/1992

06/08/1992

SAMPLE NO.	SAMPLE DESCRIPTION	DATE TAKEN
122072	EM920291 (Plating)	01/02/1992

Cyanide, Total	<0.005	mg/L
Cadmium, GFAA	0.0131	mg/L
Chromium, Total GFAA	0.748	mg/L
Copper	0.121	mg/L
Lead, GFAA	0.0053	mg/L
Nickel, GFAA	0.014	mg/L
Silver, GFAA	<0.0010	mg/L
Zinc	0.050	mg/L

SAMPLE NO.	SAMPLE DESCRIPTION	DATE TAKEN
122073	EM920292 (PC Board)	01/02/1992

Cyanide, Total	<0.005	mg/L
Cadmium, GFAA	0.0036	mg/L
Chromium, Total GFAA	0.0145	mg/L
Copper	5.00	mg/L
Lead, GFAA	0.64	mg/L
Nickel, GFAA	0.015	mg/L
Silver, GFAA	<0.0010	mg/L
Zinc	1.13	mg/L

APPENDIX B

DATA FROM THE EVALUATION OF
THE SODIUM SULFIDE/FERROUS SULFATE PROCESS

**RESULTS OF JAR TESTING WITH THE SODIUM SULFIDE/FERROUS SULFATE
PROCESS FOR WASTEWATER SAMPLE COLLECTED FROM THE CAFB CCF (BUILDING
262) MAY 9, 1991**

Jar	S ⁻² (mg/L)	Fe ⁺² (mg/L)	Ph	Betz®1195 (mg/L)	Betz®1120 (mg/L)	Cr ⁺⁶ (mg/L)
1	15	10	7.38	20	0.5	BDL
2	15	15	7.36	20	0.5	BDL
3	15	20	7.32	20	0.5	BDL
4	15	30	7.31	20	0.5	BDL
5	15	40	7.40	20	0.5	BDL
6	15	50	7.36	20	0.5	BDL

Comments:

After Adding All Reagents-Floc Is Visible On Bottom Of All Samples While
Slow Stirring No Settling Or Clearing Occurred In Any Of The Samples

Jar	S ⁻² (mg/L)	Fe ⁺² (mg/L)	pH	Betz®1195 (mg/L)	Betz®1120 (mg/L)	Turbidity (FTU)
1	15	75	7.15	20	0.5	OVERRANGE
2	15	100	7.38	20	0.5	OVERRANGE
3	15	125	7.18	20	0.5	81
4	15	150	7.48	20	0.5	96
5	15	200	7.39	20	0.5	44
6	15	300	7.44	20	0.5	45

Comments:

1 And 2 Are Dark After Adding Iron
3 And 4 Are Partially Dark
5 And 6 Are Pretty Clear
After Adding Polymer, #3 Looked Best
It Was Clearest And Had The Best Settling.
1 And 2 Were Dark (No Settling)
5 And 6 Were Light (No Settling)
4's Not Too Bad, But 3 Is Best

RESULTS OF JAR TESTING WITH THE SODIUM SULFIDE/FERROUS SULFATE PROCESS FOR
WASTEWATER SAMPLE COLLECTED FROM THE CAFB CCF (BUILDING 262) MAY 9, 1991
(Continued)

Jar	S ⁻² (mg/L)	Fe ⁺² (mg/L)	pH	Betz®1195 (mg/L)	Betz®1120 (mg/L)	Turbidity (FTU)
1	0	125	7.15	20	0.5	Overrange
2	5	125	7.38	20	0.5	Overrange
3	10	125	7.18	20	0.5	Overrange
4	15	125	7.48	20	0.5	Overrange
5	20	125	7.39	20	0.5	Overrange
6	25	125	7.44	20	0.5	Overrange

Comments:

Added Sulfide First, After Adding Ferrous, 1-3 Did
Not Change In Appearance
4 Looks Pretty Good
5 And 6 Are Black Before Mixing And After
Adding Polymers
4 Looks Best
1, 2, And 3 Have No Color Change
5 And 6 Are Black

**RESULTS OF JAR TESTING WITH THE SODIUM SULFIDE/FERROUS SULFATE PROCESS
FOR WASTEWATER SAMPLE COLLECTED FROM THE CAFB CCF (BUILDING 262) DECEMBER
17, 1991**

	Sulfide (mg/L)	Ferrous (mg/L)	Betz®1195 (mg/L)	Betz®1120 (mg/L)	pH	Turbidity (FTU)
1	0.50	0.00	10.00	0.50	7.5	26
2	0.50	0.50	10.00	0.50	7.5	22
3	0.50	1.00	10.00	0.50	7.4	24
4	0.50	1.50	10.00	0.50	7.5	24
5	0.50	2.00	10.00	0.50	6.8	22
6	0.50	2.50	10.00	0.50	7.5	20

Comments:

Good Floc Formation, Off-White Color, Light

Turbidity of Untreated 140 FTU

Turbidity of Untreated Filtered Sample is 124 FTU

	Sulfide (mg/L)	Ferrous (mg/L)	Betz®1195 (mg/L)	Betz®1120 (mg/L)	pH	Turbidity (FTU)
1	1.00	0.00	10.00	0.50	7.4	27
2	1.00	0.50	10.00	0.50	7.5	26
3	1.00	1.00	10.00	0.50	7.5	19
4	1.00	1.50	10.00	0.50	7.5	21
5	1.00	2.00	10.00	0.50	6.9	19
6	1.00	2.50	10.00	0.50	6.9	21

Comments:

Excellent Floc Formation in All Jars. Good Settling

Light Cream Color Floc

**RESULTS OF JAR TESTING WITH THE SODIUM SULFIDE/FERROUS SULFATE PROCESS
FOR WASTEWATER SAMPLE COLLECTED FROM THE CAFB CCF (BUILDING 262) DECEMBER
17, 1991 (Continued)**

	Sulfide (mg/L)	Ferrous (mg/L)	Betz®1195 (mg/L)	Betz®1120 (mg/L)	pH	Turbidity (FTU)
1	1.50	0.00	10.00	0.50	7.4	25
2	1.50	0.50	10.00	0.50	7.3	24
3	1.50	1.00	10.00	0.50	7.3	26
4	1.50	1.50	10.00	0.50	7.2	26
5	1.50	2.00	10.00	0.50	7.3	27
6	1.50	2.50	10.00	0.50	7.3	26

Comments:

Floc Becoming Darker, Brown-Black
Smaller Floc. Good Floc Formation Throughout

	Sulfide (mg/L)	Ferrous (mg/L)	Betz®1195 (mg/L)	Betz®1120 (mg/L)	pH	Turbidity (FTU)
1	2.00	0.00	10.00	0.50	7.4	33
2	2.00	0.50	10.00	0.50	7.3	27
3	2.00	1.00	10.00	0.50	7.3	28
4	2.00	1.50	10.00	0.50	7.2	34
5	2.00	2.00	10.00	0.50	7.3	32
6	2.00	2.50	10.00	0.50	7.3	29

Comments:

Solution Becomes Dark with Sulfide Addition
Floc Dark for All the Jars
Smaller Floc. Settling Becoming Poor

**RESULTS OF JAR TESTING WITH THE SODIUM SULFIDE/FERROUS SULFATE PROCESS
FOR WASTEWATER SAMPLE COLLECTED FROM THE CAFB CCF (BUILDING 262)
DECEMBER 17, 1991 (Continued)**

	Sulfide (mg/L)	Ferrous (mg/L)	Betz®1195 (mg/L)	Betz®1120 (mg/L)	pH	Turbidity (FTU)
1	1.00	1.00	0.00	0.50	7.4	76
2	1.00	1.00	5.00	0.50	7.4	60
3	1.00	1.00	10.00	0.50	7.4	24
4	1.00	1.00	15.00	0.50	7.4	12
5	1.00	1.00	20.00	0.50	7.4	8
6	1.00	1.00	25.00	0.50	7.4	10

Comments:

Jar Number 6 has Too Much Polymer, Appears Stringy in the Jar
Jars Number 4 and 5 Looks Like It has Best Floc Formation

	Sulfide (mg/L)	Ferrous (mg/L)	Betz®1195 (mg/L)	Betz®1120 (mg/L)	pH	Turbidity (FTU)
1	1.00	1.00	20.00	0.00	7.4	98
2	1.00	1.00	20.00	0.25	7.4	42
3	1.00	1.00	20.00	0.50	7.4	31
4	1.00	1.00	20.00	0.75	7.4	28
5	1.00	1.00	20.00	1.00	7.4	31
6	1.00	1.00	20.00	1.50	7.4	37

**RESULTS OF JAR TESTING WITH THE SODIUM SULFIDE/FERROUS SULFATE PROCESS
FOR WASTEWATER SAMPLE COLLECTED FROM THE CAFB CCF (BUILDING 262)
DECEMBER 17, 1991 (Continued)**

	Sulfide (mg/L)	Ferrous (mg/L)	Betz®1195 (mg/L)	Betz®1120 (mg/L)	pH	Turbidity (FTU)
1	0	0	0	0.5	7.6	74
2	0	0	5	0.5	7.6	73
3	0	0	10	0.5	7.6	26
4	0	0	15	0.5	7.6	14
5	0	0	20	0.5	7.6	12
6	0	0	25	0.5	7.6	10

APPENDIX C

DATA FROM THE EVALUATION OF THE FENTON PROCESS

FENTON REACTION DATA

pH = 6.65 Cr+6 = 0.025 mg/L					
COD = 1020 mg/L					
Test	pH	Fe ²⁺ (mg/L)	pH	H ₂ O ₂ (mg/L)	COD (mg/L)
1	4.5	200	3-5	494	198
2	3-5	200	3-5	706	117
3	3-5	200	3-5	1978	94
4	3-5	200	3-5	3955	80
5	3-5	200	3-5	5933	71
6	3-5	200	3-5	7910	74
7	3-5	50	3-5	494	463
8	3-5	100	3-5	706	118
9	3-5	200	3-5	1978	92
10	3-5	400	3-5	3955	65
11	3-5	600	3-5	5933	75
12	3-5	800	3-5	7910	75
13	3-5	100	3-5	5933	921
14	3-5	200	3-5	5933	119
15	3-5	400	3-5	5933	113
16	3-5	600	3-5	5933	94
17	3-5	800	3-5	5933	94
18	3-5	1000	3-5	5933	88
19	3-5	200	3-5	1978	66
20	3-5	200	3-5	2825	68
21	3-5	200	3-5	3531	54
22	3-5	200	3-5	4238	54
23	3-5	200	3-5	4944	34
24	3-5	200	3-5	5933	44
25	3-5	200	3-5	4944	43
26	3-5	250	3-5	4944	45
27	3-5	300	3-5	4944	51
28	3-5	200	3-5	5933	47
29	3-5	250	3-5	5933	42
30	3-5	300	3-5	5933	48

FENTON REACTION DATA (Continued)

SAMPLE	pH	Fe ⁺² (mg/L)	H ₂ O ₂ (mg/L)	pH	COD (mg/L)
1	3-5	100	2000	3-5	184
2	3-5	100	3000	3-5	187
3	3-5	100	4000	3-5	183
4	3-5	100	5000	3-5	186
5	3-5	100	6000	3-5	184
6	3-5	150	2000	3-5	166
7	3-5	150	3000	3-5	184
8	3-5	150	4000	3-5	186
9	3-5	150	5000	3-5	186
10	3-5	150	6000	3-5	185
11	3-5	200	2000	3-5	180
12	3-5	200	3000	3-5	177
13	3-5	200	4000	3-5	186
14	3-5	200	5000	3-5	183
15	3-5	200	6000	3-5	185
16	3-5	250	2000	3-5	172
17	3-5	250	3000	3-5	187
18	3-5	250	4000	3-5	184
19	3-5	250	5000	3-5	185
20	3-5	250	6000	3-5	187

FENTON REACTION DATA (Continued)

SAMPLE	pH	Fe ⁺² (mg/L)	H ₂ O ₂ (mg/L)	pH	COD (mg/L)
1	3-5	100	2000	3-5	184
2	3-5	150	2000	3-5	176
3	3-5	200	2000	3-5	180
4	3-5	250	2000	3-5	172
5	3-5	100	3000	3-5	187
6	3-5	150	3000	3-5	184
7	3-5	200	3000	3-5	177
8	3-5	250	3000	3-5	187
9	3-5	100	4000	3-5	183
10	3-5	150	4000	3-5	186
11	3-5	200	4000	3-5	186
12	3-5	250	4000	3-5	184
13	3-5	100	5000	3-5	186
14	3-5	150	5000	3-5	186
15	3-5	200	5000	3-5	183
16	3-5	250	5000	3-5	185
17	3-5	100	6000	3-5	184
18	3-5	150	6000	3-5	185
19	3-5	200	6000	3-5	185
20	3-5	250	6000	3-5	187

FENTON REACTION DATA (Continued)

SAMPLE	pH	Fe ⁺² (mg/L)	H ₂ O ₂ (mg/L)	pH	COD (mg/L)
1	3-5	100	2000	3-5	250
2	3-5	125	2000	3-5	216
3	3-5	150	2000	3-5	142
4	3-5	200	2000	3-5	143
5	3-5	250	2000	3-5	138
6	3-5	100	3000	3-5	200
7	3-5	125	3000	3-5	182
8	3-5	150	3000	3-5	112
9	3-5	200	3000	3-5	128
10	3-5	250	3000	3-5	146

THE EFFECT OF SULFIDE AND FERROUS ADDITION ON THE CHROMIUM REDUCTION AND THE FINAL SOLUTION TURBIDITY AFTER TREATMENT WITH FENTON REAGENT FOR COD REMOVAL

Test	Cr ⁺⁶ (mg/L)	S ⁻² (mg/L)	Fe ⁺² (mg/L)	Betz® 1195 (mg/L)	Betz® 1120 (mg/L)	Turbidity (FTU)	Cr ⁺⁶ (mg/L)
1	0.00	1.5	0.0	10	0.5	4	0.00
2	0.00	2.0	0.0	10	0.5	3	0.00
3	0.00	2.5	0.0	10	0.5	0	0.00
4	0.00	3.0	0.0	10	0.5	7	0.00
5	0.00	3.5	0.0	10	0.5	14	0.00
6	10.0	12.5	0.0	10	0.5	25	8.50
7	10.0	18.8	0.0	10	0.5	21	0.26
8	10.0	25.0	0.0	10	0.5	19	0.18
9	10.0	31.3	0.0	10	0.5	16	0.11
10	10.0	37.5	0.0	10	0.5	13	0.06
11	10.0	13.3	20.0	10	0.5	17	5.00
12	10.0	20.0	20.0	10	0.5	11	2.75
13	10.0	26.6	20.0	10	0.5	10	1.00
14	10.0	33.3	20.0	10	0.5	0	0.03
15	10.0	39.9	20.0	10	0.5	1	0.03
15	10.0	35.0	25.0	10	0.5	1	0.00

HEAVY METAL CONCENTRATION OF EFFLUENT WASTEWATER AFTER TREATMENT WITH 2.5 mg/L SULFIDE VS TREATMENT WITH CAUSTIC

SAMPLE	Ni (mg/L)	Zn (mg/L)	P (mg/L)	COD (mg/L)
DISCHARGE REQUIREMENTS MONTHLY AVERAGE	3.98	2.61		
DISCHARGE REQUIREMENT DAILY MAXIMUM	2.38	1.48		
RAW SAMPLE 7/09/91	0.03	0.50	26.25	1100
RAW SAMPLE 7/09/91 FILTERED	0.01	0.40	19.06	600
TREATED FOR COD TREATED WITH 2.5 mg/L SULFIDE	0.05	0.35	3.13	47
TREATED FOR COD pH ADJUSTED TO 8.5 WITH CAUSTIC	0.03	0.25	4.00	47

APPENDIX D

DATA FROM THE EVALUATION OF THE BRINECELL®

EVALUATION OF THE BRINECELL®

SAMPLE = CAFB NO DILUTION SAMPLE SIZE = 2L				
pH = 5 INITIAL COD = 1100SALT (10 g/L)				
SAMPLE	DURATION (min)	TEMP (C)	POWER (amps)	COD (mg/L)
0	0	21		1100
30	30	25	8	1000
31	40	31	9	960
32	50	40	10	780
33	60	46	10	620
34	70	55	10	580
35	80	64	12	320
36	90	72	13	280
37	100	80	14	250
38	110	84	14	190
39	120	90	16	0

EVALUATION OF THE BRINECELL®

SAMPLE = CAFB		NO DILUTION		
SAMPLE SIZE = 3L				
pH = 5 INITIAL COD = 1100SALT (10 g/L)				
SAMPLE	DURATION (min)	TEMP (C)	POWER (amps)	COD (mg/L)
0	0	21		1100
1	15	30	10	740
2	30	38	10	480
3	45	26	8	440
4	60	26	8	390
5	75	26	8	320
6	90	30	8	320
7	105	29	8	310
8	120	30	8	300
SAMPLE COOLED BY PULLING OUT 1 LITER AT A TIME AND COOLING IN ICE, SOME ICE HAD TO BE ADDED TO THE SAMPLE (APPROXIMATELY 500 mL)				

EVALUATION OF THE BRINECELL®

TEST	SAMPLE VOLUME (mL)	WATER (mL)	NaCl (g/L)	pH	Duration (min)	COD (mg/L)
1	200	1800	0.10	6-7	60	56
2	200	1800	0.25	6-7	60	47
3	200	1800	0.50	6-7	60	55
4	200	1800	1.0	6-7	60	SALT INTERFERENCE
5	200	1800	2.0	6-7	60	24
6	2000	0	0.5	6-7	60	SALT INTERFERENCE
7	2000	0	1	6-7	60	1000
8	2000	0	2	6-7	60	1040
9	2000	0	3	6-7	60	960
10	2000	0	4	6-7	60	590
15-1	2000	0	10	5	60	40
15-2	2000	0	10	5	120	0
15-3	2000	0	10	5	180	0
15-4	2000	0	10	5	210	VIAL LEAKED

EVALUATION OF THE BRINECELL®

CAFB WASTEWATER; 1/10 DILUTION TO 2 LITER				
0.75 G/L SALT				
SAMPLE	TIME (min)	TEMP (C)	POWER (amp)	COD (mg/L)
1	15	17	<1	68
2	30	18	1	55
3	45	20	1	40
4	60	22	2	33
CAFB WASTEWATER; 1/10 DILUTION TO 2 LITER				
0.5 G/L SALT				
SAMPLE	TIME (min)	TEMP (C)	POWER (amp)	COD (mg/L)
1	15	24	1	79
2	30	25	1	69
3	45	26	1	44
4	60	27	1	37
CAFB WASTEWATER; 1/10 DILUTION TO 2 LITER				
0.25 G/L SALT				
SAMPLE	TIME (min)	TEMP (C)	POWER (amp)	COD (mg/L)
1	15	20	<1	101
2	30	20	<1	72
3	45	22	<1	63
4	60	22	<1	53

EVALUATION OF THE BRINECELL®

CAFB WASTEWATER; 2 LITER SAMPLE				
20 G/L SALT				
SAMPLE	TIME (min)	TEMP (C)	POWER (amp)	COD (mg/L)
1	15	6	12	14
2	30	20	18	0
3	45	34	16	3
4	60	40	POWER OFF	0
5	75	40	POWER OFF	2
6	90	40	POWER OFF	0
7	105	39	POWER OFF	0
8	120	39	POWER OFF	0
CAFB WASTEWATER; 1/10 DILUTION TO 2 LITER				
2 G/L SALT				
SAMPLE	TIME (min)	TEMP (C)	POWER (amp)	COD (mg/L)
1	15	30	2	21
2	30	32	2	7
3	45	34	2	0
4	60	36	2	0
5	75	30	2	1
6	90	30	2	0
7	105	32	2	1
8	120	33	2	0

EVALUATION OF THE BRINECELL®

CAFB WASTEWATER; 1/10 DILUTION TO 2 LITER				
1.5 G/L SALT				
SAMPLE	TIME (min)	TEMP (C)	POWER (amp)	COD (mg/L)
1	15	28	2	30
2	30	30	2	17
3	45	32	2	0
4	60	33	2	0
5	75	37	2	0
6	90	37	2	0
7	105	40	2	0
8	120	40	2	0
CAFB WASTEWATER; 1/10 DILUTION TO 2 LITER				
1 G/L SALT				
SAMPLE	TIME (min)	TEMP (C)	POWER (amp)	COD (mg/L)
1	15	24	1	38
2	30	27	2	20
3	45	27	2	5
4	60	28	2	0
5	75	30	2	0
6	90	31	2	0
7	105	32	2	0
8	120	33	2	0

APPENDIX E

DATA FROM THE EVALUATION OF CARBON POLISHING

COD REMOVAL AS A FUNCTION OF CARBON ADDITION

Sample	Initial Carbon Weight (grams)	COD Removed (mg)
Tigg Corporation		
1	0.1075	5.2
2	0.2195	8.4
3	0.4208	10.8
4	1.0830	13.2
5	1.6963	12.0
6	2.0795	14.8
Norit Corporation		
1	0.1060	0.0
2	0.2207	4.4
3	0.4970	6.0
4	0.9722	10.0
5	1.5297	11.6
6	2.0945	12.4
COD before carbon addition was 147 mg/L Sample Size for the tests was 200 mL		

DATA FROM THE EVALUATION OF THE ACTIVATED CARBON ON A SAMPLE OF WASTEWATER
TREATED WITH THE SODIUM SULFIDE/FERROUS SULFATE PROCESS

Tigg Powder Carbon					
Sample	Volume	Carbon	Duration (hr)	Final COD (mg/L)	COD Removed (mg)
1	200	2.0481	17	97	20.6
2	200	4.0429	17	91	21.8
3	200	6.0725	17	98	20.4
4	200	8.0034	17	105	19.0
5	200	10.3321	17	78	24.4
6	200	15.4635	17	65	27.0
Norit Granular Activated Carbon					
Sample	Volume (mL)	Carbon (gram)	Duration (hr)	Final COD (mg/L)	COD Removed (mg)
1	200	2.0022	17	129	14.2
2	200	3.9872	17	91	21.8
3	200	6.0929	17	79	24.2
4	200	7.9913	17	71	25.8
5	150	10.209	17	58	21.3
6	150	17.038	17	48	22.8

DATA FROM THE EVALUATION OF ACTIVATED CARBON ON A SAMPLE TREATED WITH THE FENTON
PROCESS AND THE SODIUM SULFIDE/FERROUS SULFATE PROCESS

Sample	Volume (mL)	Carbon (gram)	Final COD 30 min (mg/L)	Final COD 60 min (mg/L)	Final COD 120 min (mg/L)	Final COD 19 hr (mg/L)	COD Removed (mg)
Norit Powder							
1	200	0.5025	155	140	137	157	8.6
2	200	1.0042	143	131	126	140	12.0
3	200	2.0063	127	129	118	128	14.4
4	200	4.0005	131	115		124	15.2
5	200	6.0030	124	111	109	118	16.4
6	200	10.0574		111	120	110	18.0
7	150	25.0582			47		30.6
Norit Granular							
1	200	0.5070	171	158	153	160	8.0
2	200	1.0014	171	146	140	152	9.6
3	200	2.0042	171	124	123	157	8.6
4	200	4.0006	143	124	115	120	16.0
5	200	6.0093	160	131	110	124	15.2
6	200	10.0642	158	120	116	112	17.6
7	150	25.0287			55		29.0
Tigg Powder							
1	200	0.5016	157	134	133	151	9.8
2	200	1.0031	146	143	136	151	9.8
3	200	2.0159	138	116	133	137	12.6
4	200	4.0080	141	118	117	123	15.4
5	200	6.0276	143	120	106	112	17.6
6	200	10.0392		121	116	105	19.0
7	150	25.0067			90		22.0

APPENDIX F

DATA FROM THE EVALUATION OF
THE BAG FILTER

BAG FILTER TEST, SAMPLE AFTER SULFIDE, FERROUS, CATIONIC AND ANIONIC POLYMER ADDITION				
SAMPLE TAKEN 5 MINUTES AFTER STARTUP				
		INFLUENT (mg/L)	EFFLUENT (mg/L)	
	COPPER	0.178	0.248	
	IRON	0.331	0.360	
	LEAD	0.257	0.220	
	NICKEL	0.098	0.067	
DATE	TIME	DURATION (hr)	TURBIDITY (FTU)	PRESSURE (psi)
08/08/91	08:15	0.00		
08/08/91	09:10	0.92	173	0
08/08/91	10:10	1.83	154	0
08/08/91	11:10	2.75	182	0
08/08/91	13:30	5.08	241	0
08/09/91	08:00	24.00	257	0
BAG FILTER TEST, SAMPLE AFTER SULFIDE, FERROUS, CATIONIC AND ANIONIC POLYMER ADDITION				
DATE	TIME	DURATION (hr)	TURBIDITY (FTU)	PRESSURE (psi)
08/16/91	08:50	0.00	78	0
08/16/91	10:50	2.00	86	0
08/17/91	08:00	23.00	95	0

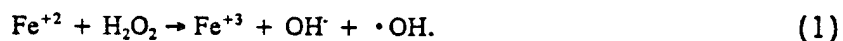
BAG FILTER TEST, SAMPLE AFTER SULFIDE, FERROUS, CATIONIC AND ANIONIC POLYMER ADDITION				
SEAL INSTALLED				
DATE	TIME	DURATION (hr)	TURBIDITY (FTU)	PRESSURE (psi)
08/27/91	08:15	0.00	17	0
08/27/91	08:40	0.42	55	5
08/27/91	08:46	0.52	60	10
08/27/91	08:56	0.68	46	15
08/27/91	09:00	0.75	68	20
08/27/91	09:04	0.82	92	25
08/27/91	14:26	6.18	163	25
BAG FILTER TEST, SAMPLE AFTER SULFIDE, FERROUS, CATIONIC AND ANIONIC POLYMER ADDITION				
ALL SEALS IN PLACE--TEMPORARY FIX				
DATE	TIME	DURATION (min)	TURBIDITY (FTU)	PRESSURE (psi)
08/28/91	09:25	0	0	0
08/28/91	09:40	15	0	25

APPENDIX G

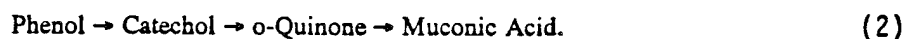
REVIEW AND EVALUATION PROCESSES FOR TOXIC ORGANIC REMOVAL

OXIDATION WITH HYDROGEN PEROXIDE

Oxidation of organic wastewater with hydrogen peroxide (H_2O_2) is usually a slow process. However in the presence of a catalyst, the oxidation process proceeds rapidly (References 1-13). Catalysts include ferrous iron, copper, aluminum, and chromium. Ferrous iron is a good selection since it is not listed as a heavy or toxic metal and its use and subsequent precipitation does not create further hazardous waste problems. Hydrogen peroxide in combination with a ferrous iron salt is commonly referred to as Fenton reagent. This reagent acts as an oxidizing agent through the formation of hydroxyl-free radicals (References 1-4):



The Fenton reagent can act as an oxidizing agent for compounds such as alcohols, ketones, benzene, and phenols. The reaction with phenol proceeds as shown in Reaction 7 (References 1-4).



Optimum oxidation of phenol is achieved when 1 mole of phenol is treated with 1 mole of ferrous salt and 3 moles of hydrogen peroxide. However, in the presence of acetate or phosphate buffers, the reaction kinetics are slower. Halogenated phenols are oxidized rapidly with the reaction rate decreasing according to the following order: $\text{Cl} > \text{Br} > \text{I}$ (Reference 1). The extent of destruction is determined by the initial hydrogen peroxide concentration, while the reaction time is determined by the iron concentration (References 1-4).

The formation of intermediate products (semiquinones) produces a dark brown color. At the completion of the reaction, the solution is yellow or

orange because of the presence of the ferric iron; the ferric iron can be precipitated by increasing the pH with lime or caustic. Alum can be added to aid in floc formation. Some coprecipitation of the remaining organics occur, and depending on the effluent discharge requirements, the effluent may be sent to a domestic sewage treatment plant or biological Industrial Wastewater Treatment Plant (IWTP).

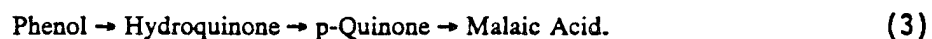
The Fenton reagent has been used to treat stripped refinery effluent and steel plant effluent (Reference 1). The stripped refinery effluent had a total chemical oxygen demand (COD) of 970 mg/L of which 280 mg/L of this was due to the presence of phenol. (Note: Each mg/L of phenol (C_6H_6O) is equivalent to 6 mg/L of COD.) Nine moles of hydrogen peroxide and 1 mole of ferrous ammonium sulfate was added per mole of phenol. The COD remaining due to phenol after reaction at pH 4 and 50 °C for 30 minutes was 2 mg/L. The total COD remaining was 246 mg/L (Reference 1).

Commercial treatment units are available through Technotreat Corporation of Tulsa, Oklahoma, and Peroxidation Systems of Tuscon, Arizona (References 4, 12, and 13). Interlox America of Houston, Texas, provides a number of publications and brochures on the treatment process and the chemicals used in the treatment.

OXIDATION WITH POTASSIUM PERMANGANATE

Certain naturally occurring organic refractories or residual organics can be readily oxidized by potassium permanganate (Reference 14). Functional groups are critical in determining whether or not a compound can be oxidized by potassium permanganate. The carboxyl group, carbonyl group, and hydroxyl group of alcohols resist oxidation, while the carbonyl group of aldehydes, the amino group of amines, and the carbon-carbon double bond of unsaturated compounds are readily oxidized by potassium permanganate. However, oxidation does not proceed at neutral or higher pH (Reference 14).

Aromatic compounds require greater concentration of potassium permanganate. Approximately 9.3 moles of potassium permanganate was required to oxidize 1 mole of phenol to malaic acid. The reaction proceeds as follows (Reference 14):



The effluent requires further treatment to precipitate the manganese. Depending on discharge requirements, further organic treatment may be required to further the COD concentration.

WET AIR OXIDATION

Wet air oxidation can effectively treat aqueous waste that is too dilute for cost effective incineration but too concentrated (too toxic) for biological treatment (References 15-21). Wet air oxidation is the aqueous-phase oxidation of organic and inorganic materials at elevated temperatures (347-608 °F) and pressures (300-3,000 psig); the solubility of oxygen in aqueous solutions is enhanced at these temperatures and pressures. The process relies on the heat of oxidation to raise the temperature to the required operating level. For the reaction to be self-sustaining (no auxiliary reaction fuel), the initial COD must be at least 15,000 mg/L.

The required oxygen is provided by compressed air. The oxidation products are primarily carbon dioxide and water. Sulfur is converted to sulfate, and nitrogen is converted to ammonia; these stay in the aqueous phase. Metals remain in the aqueous phase and can be precipitated prior to discharge. The heat from the treated wastestream can be used to generate steam.

Halogenated aromatic compounds without other nonhalogenated functional groups are relatively resistant to wet air oxidation. However, electron-donating constituents such as hydroxyl, amino, or methyl groups make aromatic rings more susceptible to destruction by wet air oxidation.

Wet air oxidation has been demonstrated on the pilot scale by MODAR at CECO International, Inc.'s, Niagara Falls, New York, hazardous waste treatment and disposal facility (References 17 and 18). The process was demonstrated using a dilute isopropyl alcohol stream contaminated with priority pollutants including 1,1,2-trichloroethane, nitrobenzene, and 2-chlorophenol and a dielectric fluid containing polychlorinated biphenyls (PCBs). The pilot unit had an organic material flow capacity of 50 gal/day. Greater than 99.99 percent destruction of the organics was demonstrated.

Wet air oxidation has also been demonstrated on the pilot scale by several other companies, including Zimpro in Rothschild, Wisconsin (Reference 19). Zimpro treated sewage sludge and industrial waste sludges from paper and textile mills. Approximately 3,400 kW-hr/day power was required to reduce the COD by 50 percent on 10,000 pounds of sludge containing 70 g/L of COD.

MODAR is working with ABB Lummus Crest to scaleup the process, and they expect full-scale demonstration in the near future. An estimated capital cost of \$15 million for a 10,000 gal/day wastestream containing sufficient organics to be self-sustaining was obtained from ABB Lummus Crest (Reference 20).

A wet air oxidation demonstration unit (10,000 to 12,000 gal/day) has been in operation for 4 years in Mississauga, Ontario, Canada. The unit has been treating waste containing up to 250,000 mg/L COD, reducing the COD by 89 percent. Oils and greases are reduced by 99 percent, naphthalene by 99 percent, cresol by 94 percent, polyethylene glycol by 98 percent, and trimethylbenzene by 99 percent (Reference 21).

INCINERATION

Incineration relies on the heat of combustion to raise the temperature to the required operating level. Approximately 300,000 to 400,000 mg/L COD is required for the process to be self-sustaining (Reference 15). Operating temperatures are 1,500-2,000 °F. With the required scrubbers for the off gas, incineration is an accepted method for disposal of hazardous organic-containing waste and wastewater. However, the process can be expensive, especially for wastewaters containing low concentrations of COD.

OZONATION

If sufficient ozone is added to a wastewater, essentially all the organic compounds can be oxidized to carbon dioxide and water (References 22-27). The source of the ozone can be by producing electricity with an ozone generator or by using ultraviolet light to convert the oxygen available in the wastestream to ozone; an ozone generator, although requiring more initial capital cost, is a more effective method of treatment. Generation with ultraviolet light is limited by the solubility of oxygen in the water (References 22 and 23). Additionally, it can be difficult to keep the light source clean for efficient ultraviolet light transmittal in the wastewater. The ozone generator processes air, oxygen-enriched air, or pure oxygen into ozone, and the ozonization process can be enhanced by the addition of hydrogen peroxide to the wastestream.

Complete and efficient ozonization is dependent on the type of waste, the degree of oxidation desired, the reactor or contractor configuration, and the contact time. Contractor configurations may include bubble towers or packed columns. The presence of carbonates may inhibit ozonization at high pH.

Approximately 2 to 6 mg/L ozone are required per 1 mg/L phenol. Solutions with higher initial phenol concentration react more rapidly; the ozone demand to oxidize phenol at a pH of 12 is half that required at a pH of 7 (Reference 24).

The degree of ozonization desired is dependent on what process may follow the ozonization process. For example, if a biological treatment process is available, it may be desirable to only treat the wastestream with ozone to degrade the organics to the level where they are not toxic to the biological system or can be degraded to discharge limits by the biological system. Ozonization of high molecular weight biorefractory organic compounds (humic substances) produces a lower molecular weight and more biodegradable

substance and at the same time, adds more oxygen to the wastestream for biological treatment (Reference 25).

Treatment of groundwater contaminated with 200 micrograms/Liter (ug/L) of trichloroethylene (TCE) and 20 ug/L of tetrachloroethylene (PCE) has been demonstrated on a 2,000 grams per minute (gpm) unit (References 26 and 27). To achieve 80-90 percent destruction of the contaminants, 4 mg/L ozone was required with a ratio of hydrogen peroxide to ozone of 0.5 by weight. The capital cost for the ozone generator was \$85,000; the cost of the hydrogen peroxide was approximately \$1.00/lb (Reference 27).

Brinecell® Manufacturing Corporation of Salt Lake City, Utah, offers a process for the oxidation of the organic compounds similar to ozonation (Reference 28). The Brinecell® consists of an electrolytic cell where patented Brinecell® electrodes are used to produce ozone, chlorine, chlorine dioxide, sodium hypochlorite, hydrogen peroxide, and the free radicals of these oxidizing agents. Sodium chloride is added to the solution, and a chloride-chlorine-chloride cycle takes place in the electrolytic cell. The Brinecell® has been effective in the rapid bleaching of paper pulp, cottons, and synthetics, and has been in use since 1960 for sterilizing drinking water, swimming pools, water cooling towers, and surgical instruments.

CARBON POLISHING

In carbon absorption treatment, the impurities are physically absorbed onto activated carbon. A number of factors can affect this absorption, including the particle size of the carbon and its pore size distribution, the impurity being removed, and the pH of the solution. Carbon absorption as a primary technology for total toxic organics (TTO) removal could be expensive due to the volume of carbon required for the removal and the expense of the disposal or reclamation of the spent activated carbon. However, carbon polishing can offer an economical means of ensuring TTO discharge requirements are met. The majority of the organic compounds are removed or oxidized in a primary organic treatment process such as the Fenton process, the heavy metals are removed with a metal precipitation process such as the sodium sulfide/ferrous sulfate process, and any remaining organic compounds are removed by the activated carbon "polishing" process. The carbon loading is much smaller, and thus, the carbon life is longer. This reduces the cost for replacement carbon and carbon disposal.

For the mobility and batch treatment process operation requirements of the project, the Fenton and Brinecell® processes were investigated in depth; the results of this investigation appear in Section III of the report, "Skid-Mounted Sodium Sulfide/Ferrous Sulfate Metal Precipitation Project Phase I." (See Reference 29.)

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